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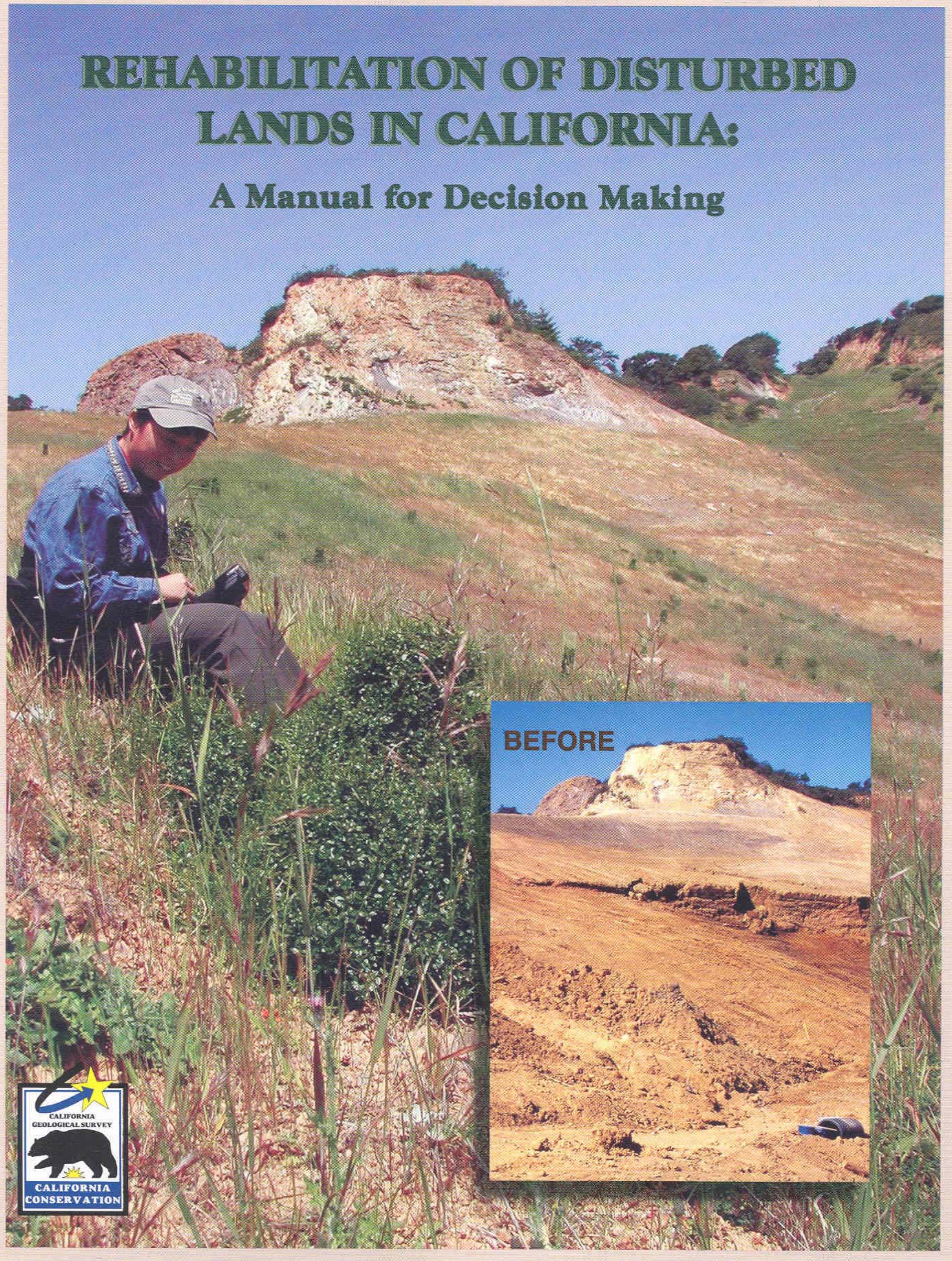
REHABILITATION OF DISTURBED LANDS IN CALIFORNIA:

A Manual for Decision Making



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REHABILITATION OF DISTURBED LANDS IN CALIFORNIA: A MANUAL FOR DECISION-MAKING

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1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this manual is to compile and synthesize the wealth of information on revegetation, rehabilitation and restoration that has become available in the last 20 years. This manual focuses on moderately to severely disturbed lands, such as those commonly associated with mining. These lands do not rehabilitate naturally in the short-term because their topsoil has been altered, inverted, or lost. This book should also provide planners and practitioners of less disturbed areas with a guide for designing projects in a wide variety of other situations where rehabilitation is needed.

Clearly, a manual such as this cannot provide a recipe that would apply to the state of California as a whole; nor can it cover every conceivable difficulty a planner might encounter. The state is simply too diverse: California encompasses the highest and lowest points in the continental US; it includes 1000 miles of coastline; it has a variety of climates; and it supports a wide range of parent materials, including unique ones such as serpentine, which are infertile or toxic and which restrict normal plant growth. This variety engenders great biological diversity, with an unusually high number of endemic and rare species. Therefore, rather than looking to this manual for what to do in a specific situation, planners or practitioners should use this manual to help them think out what would be the most logical and practical plan on a given site.

Approximately 20 years ago, in order to protect the biological diversity of California, politicians, planners, and practitioners began to place a greater emphasis on using native plants for revegetation, rehabilitation, and erosion control. Past methodologies for revegetation of mined lands had relied on placing a thin (6 inch) layer of new topsoil on the site and then reseeding with erosion control species that were largely exotic. An investigation of such projects in the United Kingdom approximately 20 years after rehabilitation found many of them in poor condition (Haigh 1992). The sites had a variety of problems: gullying, soil erosion, soil compaction, accelerated run-off, and poor vegetation cover. Many of these problems resulted from the inability of the sites to begin natural soil-forming processes (Haigh 1992). Soil-forming processes require nitrogen capital, nutrient exchange capacity, and an active community of soil organisms (Bradshaw et al. 1982), none of which were provided for in the reclamation plans for the sites. The newer approach of using native species obviates many of the conflicts inherent in using exotics, but it also obligates the project manager to think carefully about the soil into which the native species will be placed, the types of plant materials to be used, the planting plan, and preparation of the site.

Some of these considerations for safeguarding California's biodiversity have made their way into statutes and regulations, such as the California Code of Regulations, Title 14, Division 2, Chapter 8, Subchapter 1, Article 9 (Reclamation Standards), Section 3705(g). This manual goes several steps further by providing not only current research information, but also ample examples of actual projects and advice on devising test plots, planting plans, and monitoring programs. There are also many examples of sample specifications that can be used as models; such specifications help ensure that everyone working on a project knows what is expected. This manual is arranged partly chronologically, according to the order in which portions of the rehabilitation plan must be conceived of and executed. But it is also arranged partially by topic, because some topics, although they may come early in the process, can't be addressed until the background for them is thoroughly understood.

1.2 Why Rehabilitate?

While a few sites that have been minimally disturbed will recover quickly and adequately by natural processes without any human intervention, rehabilitation is necessary in many circumstances for a variety of reasons. Natural reinvasion of a site may take years, during which the disturbed site may erode. Erosion will decrease the capability of the site to support vegetation, continue to degrade the habitat and its visual quality, and increase dust pollution (Photo 1.2a). Disturbed lands can also cause significant off-site impacts such as increased sedimentation and air pollution, and they can act as a noxious weed repository.

The goal of *rehabilitation* is to re-establish some physical processes and biological components of the indigenous ecosystem, in order to develop a stable ecosystem that is capable of performing some of the ecological functions of that original ecosystem. This is a moderate but practical goal. Less ambitious projects might simply wish to accomplish *revegetation*, that is, to establish vegetation on a site without working toward a stable ecosystem that resembles what was originally there. More ambitious projects might attempt *restoration* of the site, which entails returning all or nearly all the physical and ecological processes and biological components of the indigenous ecosystem to the site. Or a project may attempt the creation of a new ecosystem on lands that did not previously support that ecosystem.

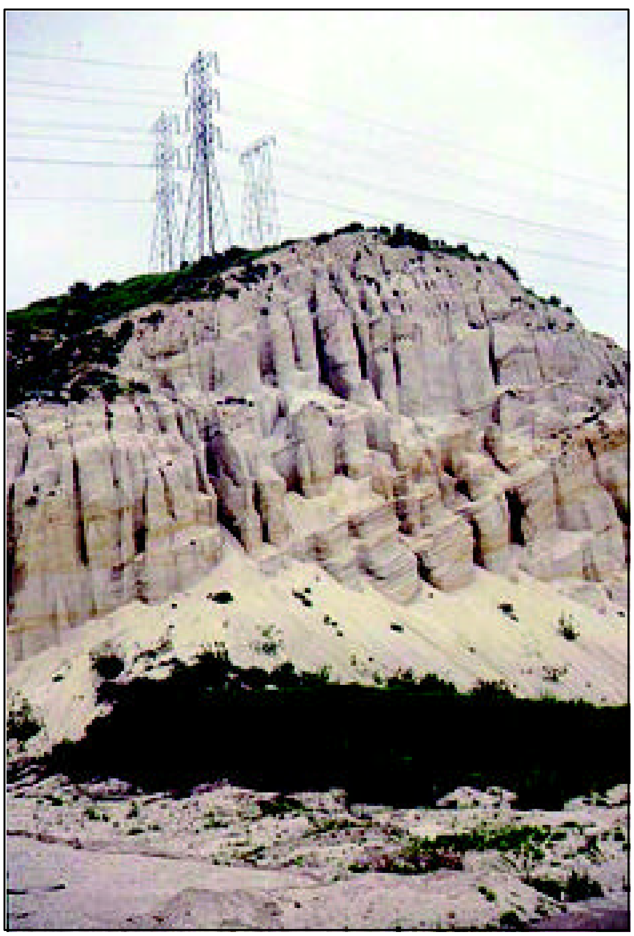


Photo 1.2a: An eroding slope left unreclaimed continues to erode and degrade adjoining habitat.

More specialized projects might aim at *reclamation*, which uses combined processes that minimize adverse environmental effects of surface-mining and that return lands to beneficial end use (Surface Mining and Reclamation Act of 1975); *reforestation*, which involves revegetation with tree species in order to yield desired wood products; *enhancement*, which alters a site for improvement of a specific value; and *landscaping*, which manipulates ecosystems for cultural values such as aesthetics and recreational access.

These terms, especially revegetation, rehabilitation, and restoration, are often used interchangeably, causing confusion among regulators and practitioners. Their definitions overlap somewhat, but it is important to keep the ideas separate, because the words used to describe a project will help to shape its goals and outcome, not to mention the expectations of all those involved. In particular, the term reclamation is used very broadly. For reclamation projects that are to result in some type of wildland vegetation, the project goal needs to be further defined using one of the other "re-"words.

This manual will largely speak to rehabilitation of wildland habitats with native plant species, as this goal is most broadly applicable. Regardless of the level of rehabilitation being attempted on a site, most projects strive at a minimum to achieve the underlying goal of sustainability by providing vegetative cover that will perpetuate itself. This vegetative cover should also protect a site from wind and water erosion in the following ways:

- intercepting raindrops, reducing their velocity and lessening the erosive effect of rainfall;
- reducing the velocity of surface runoff, thereby reducing the rate of erosion;
- sustaining plant roots, and their associated microorganisms, helping to bind soil together, increasing infiltration and reducing runoff; and
- promoting deeply rooted plants, thus providing tensile strength to slopes and decreasing the incidence of erosion, slumping, and slope failure.

Sustainability, the ability to self-perpetuate, is just one of several ecosystem functions (Ewel 1987, PERL 1990). The remaining ecosystem functions must be addressed by the practitioner during project development:

- Invasibility—the susceptibility or resistance of the site to invasions by exotic species (plants or animals).
- Resilience—the ability of the site to recover following extreme perturbations.
- Productivity—the efficacies of resource capture and use by the community.
- Transformation of nutrients—the microbial and chemical processes that control the concentrations of nutrients and other compounds, including cycling of nutrients with no net loss and the flow of energy similar to a comparable, undisturbed community.
- Biotic Interactions and Support of Food Chains—the ability of the site to support the full requirement of ecosystem organisms such as pollinators, predators, herbivores, etc.

If correctly designed, installed, and maintained, vegetation can provide all these functions at a relatively low cost and with little to no long-term maintenance requirement. In addition, a well-vegetated landscape will usually be more aesthetically pleasing and will increase the quality of life of the surroundings (Photos 1.2b and c).

Photo 1.2b: Engineered slope prepared for restoration. This slope below a development in Granada Hills, southern California, was prepared for restoration. Soil, seed, and broken brush were incorporated into the substrate, and the outer three feet of the slope were NOT compacted to the 90 percent engineering standard.

Photo 1.2c: Results of engineering for restoration-Granada Hills. Five years later, the slope has fully revegetated with native coastal sage scrub species, without the aid of irrigation and fertilization. This slope was not damaged in the following Northridge earthquake, although many slopes in the surrounding areas did experience failures.

Photos courtesy of Land Restoration Associates.

2.0 PLANNING FOR REHABILITATION

Ideally, planning for rehabilitation should begin concurrently with the designing and engineering of the project that is going to impact the site. If the engineer's specifications are already complete, the options available to the rehabilitation designer are much more limited. Working as part of a multi-disciplinary group, the rehabilitation specialist can identify vegetation and slopes that should be retained, locate problem soil areas, make recommendations as to proper grading for enhanced vegetation growth and survival, determine what level of rehabilitation is attainable, and point out habitat and aesthetic considerations.

Of course, if the impact on the site has already occurred, such as on an abandoned mine site, rehabilitation project managers must start with the site in the condition that they find it.

2.1 Project Scheduling

The scheduling of the different elements of a rehabilitation plan needs to be determined at the onset of the design of the project. It is imperative that adequate lead time be given to a rehabilitation project. Most commonly, it will take at least two years of planning and design before a project can be implemented. The reasons are both biological and political—plant materials, agencies, and companies will not always produce the desired results at just the time the planner wants them. In addition, many aspects of the plan will have a narrow window of opportunity for reliable results, and these narrow windows may dictate site development and success.

2.1.1 BIOLOGICAL SCHEDULE

Plants have a very narrow window for installation without the addition of systematic irrigation. For example, installation of containerized plants at low and moderate elevations should take place in California immediately after the first major storm (late fall—October or November). The soil profile should be wet throughout, with winter storms soon to follow. At higher elevations, where winter snowfall is common, plants need to be placed in the soil by October 1, allowing them plenty of time to go dormant before winter temperatures drop below freezing; alternatively, they may be planted after snowmelt in the spring.

This narrow window of installation also determines how far ahead of time the plant materials have to be either collected or grown out. For example, all containerized plant materials used on a site need to be grown out approximately a year before they are installed, and some species such as manzanita (*Arctostaphylos* spp.) require two years to grow out. If seeds are to be collected for the process of growing out plants in containers or for direct planting on the site, seed collection has to take place beforehand at the appropriate time of year, and often it can take more than one year to gather enough seeds of the desired species. If any live plant materials will be salvaged for later use in site rehabilitation, such salvaging should take place while the plants are dormant. For most species in California, the period of dormancy begins between October and December, depending on location, and ends about March. Transplanting while the plant is actively growing will stress the plants and increase their mortality rate.

2.1.2 EARTHWORKING SCHEDULE

From the engineering side, earthwork to prepare the site for planting and erosion control needs to take place while the site is dry (usually the summer months). If earthwork is delayed into the autumn, planting may be delayed past the biological window, requiring that irrigation, which can be costly, be added to the project design or that the project be delayed another year.

2.1.3 LAND-USE PLANNING SCHEDULE

Rehabilitation projects do not take place in a void. Local, state, or federal entities and watershed groups all have an interest in projects in their jurisdictions. The land uses around a project must be taken into account, both for project success and for good community relationships.

2.1.3.1 Zoning

Zoning issues should not be overlooked. The project planner should determine the zoning ordinances of the rehabilitation site and also of surrounding properties. Development or changes (such as flood control projects) on adjoining properties may impact the rehabilitation site. For example, a wetland rehabilitation project may be vulnerable to having its water source altered by an upstream property owner.

2.1.3.2 Permitting

The best advice on permitting is to contact the local lead agency early on in the process. Most projects will require some type of local, state, or federal permit. Permitting can take from as little as three months to three years or more, depending on the complexity of the project. The permits are obtained based upon a design, and completing the design can also be time consuming.

Each lead agency (city, county, or area-wide planning commission) will have regulations on the amount of earth moving that can take place without a grading permit and under a grading permit. Lead agencies also determine which projects will require environmental review under the California Environmental Quality Act (CEQA) and/or under the National Environmental Policy Act (NEPA). Once the application is deemed complete (30-day process) and a determination is made that the project must undergo CEQA, the lead agency has up to one year to complete the process.

Projects located in waterways may have to obtain a 1601 or 1603 Stream Alteration Permit from the Department of Fish and Game (DFG) (contact the local Regional Office), a Clean Water Act (CWA) Section 404 permit from the Army Corps of Engineers, a CWA Section 401 certification from the State Water Resources Control Board, and, if the waterway is regulated, a permit from the Federal Energy Regulatory Commission. If the project has minimal impacts, the Corps 404 Permit process has a series of Nationwide Permits available that regulate with little, if any, delay or paperwork.

Other permits may need to be obtained from the Air Quality Control Board for air impact and from the US Fish and Wildlife Service and the DFG for impacts to species listed under the federal and state endangered species acts, respectively. This information will be available from the lead agency.

2.1.3.3 Stakeholders

Watershed stakeholder groups, which are forming throughout California, are a good contact point for projects to be undertaken in their watershed. In addition, local groups may be able to provide specialized local information about the site that is not otherwise available to the practitioner, such as anecdotal information on the disturbance history of the site. The University of California at Davis maintains watershed contact information on-line at *www.ice.ucdavis.edu*. Informed neighbors make the best neighbors, and these groups can facilitate the approval and/or funding for a project in their watershed. Currently, various state grant programs target restoration projects that are supported by established watershed groups (e.g., State Water Resources 205(j) and 319(h) grants).

2.2 Rehabilitation Potential

Once the political constraints have been considered, the site's rehabilitation potential must be assessed: Can the ecosystem functions be reestablished and, if so, what habitat type or plant community can the site realistically support? Factors entering into this assessment include the physical and biological characteristics of the site and are summarized in Table 2.2 later in this section.

2.2.1 CLIMATE

The climatic diversity of California is unrivaled in the United States, providing numerous challenges to the practitioner. California's climate varies from the cool, wet Pacific Northwest to the hot dry southern deserts and from coastal marshes to alpine meadows (Figure 2.2.1). The gross climatic regime often limits the potential for plant growth on a site and affects the planning schedule. For example, arid or semi-arid climates are often difficult to rehabilitate because the correct soil-moisture regime for germination occurs infrequently. In contrast, high elevation sites can be difficult because the growing season is short. Local elevation and topography then determine to a large degree how the gross climatic regime will be expressed, i.e., whether the climatic effect will be exacerbated or ameliorated. Such localized effects may include storm movements, rain shadows, lake effects, and anabatic and catabatic winds. Practitioners need to assess both the gross climatic regime and local conditions.

2.2.2 ASPECT

Aspect determines the amount and duration of solar radiation a site receives. In the northern hemisphere, northern exposures are cooler and wetter and southern exposures are hotter and drier; eastern and western exposures fall in between these two extremes. The role of aspect in the rehabilitation potential depends on the climate of the proposed project site. For many areas in California, northern exposures provide a better growing environment than do southern exposures. However, at high elevations, the cool, wet northern exposures translate into a shorter growing season, making the site more difficult to rehabilitate.

In addition, a rehabilitation plan must be varied to accommodate the diversity of aspects on a site. For example, in many central and southern California locations, the northern exposures support diverse oak woodlands, while the southern exposures support annual grasslands (Photo 2.2.2). In this example, an attempt to create an oak woodland on a southern exposure would be ill-advised.

2.2.3 TOPOGRAPHY

An overview of the landscape-level topography will provide clues as to whether the site is in an erosional landform, with substrate material gradually leaving the site, or whether the site is a depositional landform, which receives material from upstream or uphill. The landform also generates strong soil and hydrological effects. The ability to revegetate a site will be influenced by the topography, which includes the stability of the slopes, i.e., the potential for surficial and/or deep-seated slope failure. The steeper and longer the run of the slope, the more prone the site will be to erosion, and the more difficult it will be to rehabilitate the slope (Photo 2.2.3). Also, the steeper the slope, the more droughty the slope. As one would expect, it is generally easier to revegetate gentle (no steeper than 3:1 (H:V) slopes than those approaching 1:1 (H:V).

2.2.4 SOIL DEVELOPMENT AND STRUCTURE

Soil development is determined by a number of factors such as parent material, climate, living matter, topography, and time. The degree of soil development on a site can be an important factor in determining rehabilitation potential.

For example, many forest soils and some desert soils are highly structured, with identifiable horizons and sub-horizons (Photo 2.2.4). Recreating such a highly developed soil profile after severe soil disruption is difficult. Disturbed soil is often mixed from multiple horizons, which results in the disruption of soil structure and chemistry and the dilution of beneficial soil organics and biota. Site-indigenous species may be closely tied to soil chemistry and biology, and the loss or dilution of these through mixing may have a long-term, adverse impact on the rehabilitation potential of the site.

Ecosystems that have little natural soil development or have coarse textures are often easier to rehabilitate because the soil is less susceptible to damage from handling. The importance of soil management techniques (such as stockpiling and storage) will be much less for sites that have little to no natural soil structure, i.e., moving sand dunes and riparian scour zones.

2.2.5 HYDROLOGY

Water can be both a curse and a benefit to a rehabilitation project. If a dry land habitat is to be reestablished, erosion control measures need to be

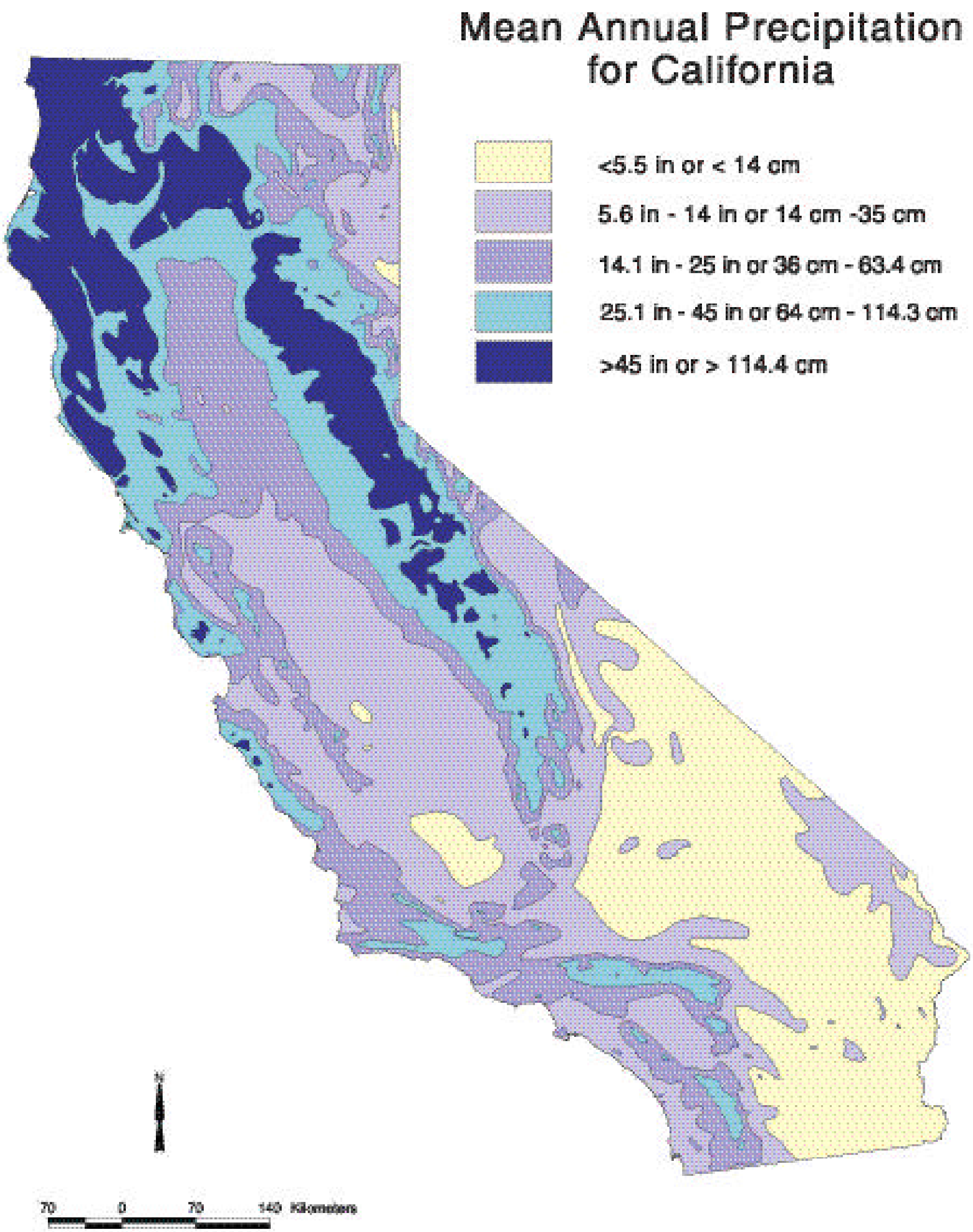


Figure 2.2.1: Mean annual precipitation for California.

Photo 2.2.2: Effect of aspect on vegetation composition. Northern aspects in this central California location are dominated by oak woodlands, while southern aspects consist of annual grasslands.

Photo 2.2.3: Effects of topography on rehabilitation. These over-steepened slopes will make it difficult to rehabilitate this mine site in southern California.

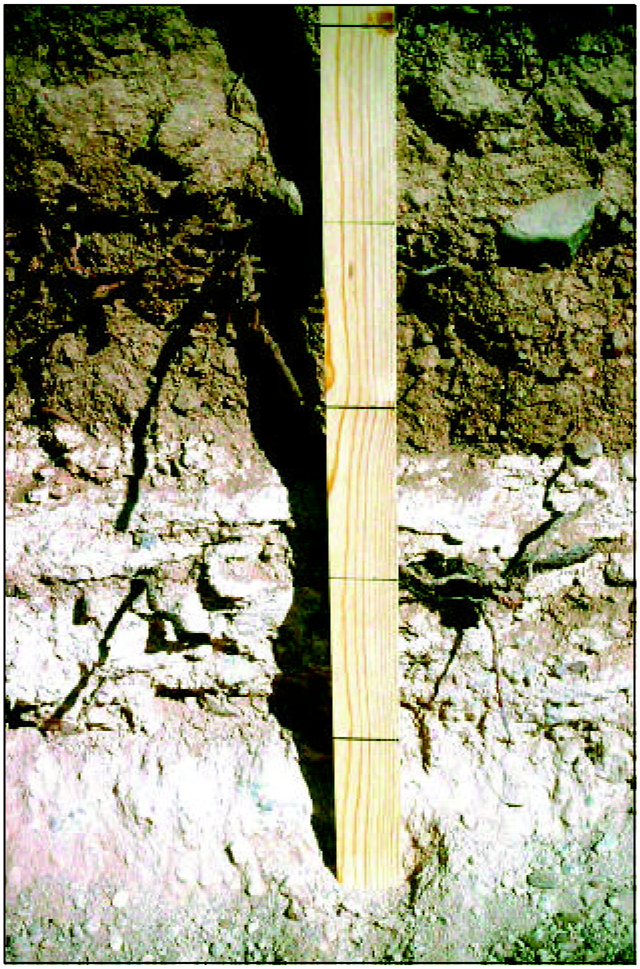


Photo 2.2.4: Example of a highly structured soil (from a Mojave Desert site).

used to protect the newly planted/denuded site from wind and water erosion. Often this involves a drainage plan that moves the water around and through the site without causing erosion.

Many of the ecosystems that are currently being rehabilitated or created in California are water-dependent systems, such as wetlands, vernal pools, and riparian woodlands. When a water-dependent system is being rehabilitated, the practitioner needs a thorough understanding of the hydrology of the site and of the water needs of the components of the system. Specifically, issues to be addressed include the physical processes that affect frequency and duration of inundation, depth of inundation, and depth to groundwater during the growing season. The long-term flooding history of the site must also be considered.

AN EXPLANATION OF SIDEBAR SPECIFICATIONS

This manual includes many examples of actual specifications from projects implemented throughout California. Each specification was written for a specific site and is provided herein as an example only. These specifications can be used as a basis for writing your own site specific specifications. However, they should not be copied verbatim, but instead should be modified to reflect the characteristics of your rehabilitation site.

2.2.6 LEVEL OF DISTURBANCE AND DEGREE OF ISOLATION

The ability to rehabilitate a site will also depend on the degree of disturbance the site has experienced. A small site that has experienced little to no human alteration would be relatively easy to rehabilitate; most ecosystem functions are still evident and spontaneous colonization is still a dominant process on the site. At the opposite end of the spectrum are large, highly disturbed sites where human activities have completely altered the processes and functions of the site. On a highly disturbed site, ecosystem functions are not evident, and spontaneous regeneration of the site-indigenous species may not occur (Photo 2.2.6). The latter site will be difficult to rehabilitate.

The degree of isolation of the site will interact with the degree of disturbance. A site that is cut off from similar habitats will be more difficult to rehabilitate, because the practitioner will be responsible for the reintroduction of nearly all biota. A site that is situated near or surrounded by similar habitat will be easier to rehabilitate. These nearby, intact habitats provide the full complement of propagule sources and fauna (such as pollinators) important for biotic interactions that would otherwise be difficult to identify and/or obtain for re-introductions. For this reason, it is advisable to try to provide connections or migration corridors from adjacent intact habitats to a rehabilitation project.

AN EXPLANATION OF SUCCESSION

Succession is a concept regarding the process of ecosystem development in which the establishment of the first species in the community modifies the environment, allowing for their replacement with a sequence of populations of other species through time. Succession culminates in a "climax" community, where the populations remain relatively stable and are no longer replaced by new populations. The species found in the climax community are completely different from those found in the early successional stages. The theory of succession was developed on abandoned fields and meadows in Wisconsin and has limited applicability in California.

2.2.7 ECOLOGY

The choice of the target ecosystem (that is, the ecosystem that is the ultimate goal of the rehabilitation project) must fit with the physical characteristics of the site as discussed above, as well as with its ecological characteristics. One important ecological characteristic (or factor) is the site's resiliency, its ability to recover from perturbations. Resiliency is related to the frequency and the magnitude of natural disturbances with which an ecosystem has evolved. For example, old growth forests and some desert systems naturally experience infrequent or low levels of disturbance and, therefore, have little innate resilience. Old growth forests have evolved in a relatively stable environment and do not quickly regenerate following frequent or high levels of disturbance.

Coastal sand dunes and riparian woodlands are at the other end of the spectrum. These systems are adapted to frequent and/or high levels of disturbances and exhibit considerable resilience. The vegetation of wind-blown sand dunes and flood-prone streams is dominated by species that resprout or reseed readily following a disturbance, making the site relatively easy to rehabilitate. Thus the life cycle of the plants to be used is an ecological factor to be considered in matching the rehabilitation goal to the site.

Another ecological factor to consider is succession, in which sets of species predictably follow other sets of species as the system develops soil, shade, and complexity. If a system does have successional stages, they will be an important consideration during rehabilitation. When rehabilitating a successional system, the practitioner will need to emphasize the early successional species and ecosystem structure because their life cycles are adapted to marginal conditions. However, many ecosystems in California do not exhibit what is known as classical succession: the climax species are present at the outset.

Photo 2.2.6: Loss of ecological processes. Mining on this site in the Sierran Foothills has disrupted most ecological processes, making rehabilitation difficult.

2.2.8 COMPETITION AND HERBIVORY

Invasibility, the resistance to invasions by exotic species, while part of the ecology of the site, deserves separate mention for California. Reaching a goal of site-indigenous species in California ecosystems may be difficult because many California ecosystems have been altered by invasive exotics, which have the potential to out-compete the native species and can permanently alter the resulting habitat. The most common example is the conversion of California's perennial grasslands to annual (exotic-dominated) grasslands.

If a site is dominated by highly invasive exotic plant species (examples include pampas grass (*Cortaderia* spp.), European beach grass (*Ammophila arenaria*), eucalyptus (*Eucalyptus* spp.), tamarisk (*Tamarix* spp.), and giant reed (*Arundo donax*)), control of the exotics will be necessary to re-establish the indigenous ecosystem. Often, control of exotics is very difficult and expensive; therefore, many projects tolerate some level of contamination as long as project goals are not compromised.

Other impacts to native systems include herbivory by native (deer) or by exotic (cattle) herbivores (Photo 2.2.8a). The practitioner should also assess the potential for a native rodent or insect population explosion caused by the abundance of new sprouts on the rehabilitation site.

Other impacts to native systems include damage by cattle and by people on foot and off-road vehicles. The damage from trespass (pedestrian, bovine, and vehicular) includes direct physical damage to plant materials, and compaction and accelerated erosion of soils (Photo 2.2.8b).

2.2.9 WATERSHED PROCESSES

The potential of the site to support a particular habitat will also be determined by how much the gross physical processes on the landscape-level have been changed by major land-use alterations, such as dams. Actions that seek to restore watershed processes on a site specific level, but within the context of the landscape level, will have a greater chance of success. The basic method is to identify the watershed processes, determine where and to what extent these processes have been altered, and then repair or rehabilitate the processes. Such watershed processes include water quality, sediment transport, geomorphology, wildfire recurrence, and flood attenuation. Alterations of watershed processes can dramatically affect many other factors, such as topography, hydrology, and soils.

Drastic disturbance of soils, including loss of topsoil horizons, has great potential to alter watershed dynamics. In particular, disturbed soils commonly have poor soil structure and lower infiltration rates, meaning that a greater proportion of precipitation flows over the land surface instead of percolating into the soil. These surface flows accelerate erosion. Rebuilding of soil structure takes time, and the first years of a rehabilitation project typically suffer increased erosion compared to sites with established revegetation. The cumulative effects of degraded soils in a watershed are seen in flashy, erratic flows of streams, channel downcutting, and heavier sediment transport.

Photo 2.2.8a: Grazing impact. Impacts to native systems include herbivory by native (deer) or by exotic (cattle) herbivores.

Photo 2.2.8b: Trespass impact. Off-road vehicles have damaged these slopes and increased erosion.

Table 2.2: Factors that influence rehabilitation potential

FACTOR	INFLUENCE	RANGE OF INFLUENCE
CLIMATE AND ASPECT	-Natural regeneration processes -Water availability -Growing season -Soil temperature, oxygen, and development	Favorable (i.e., long growing season, water available during growing season, etc.) Unfavorable (i.e., short growing season, seasonal or prolonged droughts, etc.)
TOPOGRAPHY	-Water availability -Soil development -Site stability (slope stability and erosion potential)	Favorable (i.e., gentle slopes, deep soils, etc.) Unfavorable (i.e., steep slopes, slumping, shallow and rocky soils, etc.)
SOIL DEVELOPMENT AND STRUCTURE	-Need to re-create the chemical, physical and biological soil structure	Favorable (i.e., little soil development such as no recognizable A horizon, no difference between A and B horizons, substrates have assorted nutrient reserves and moderate texture). Unfavorable (i.e., plant species that require well-developed soil structure such as O, A, and B horizons, hardpans, site substrates contain unbalanced nutrients, low water holding capacity, mine altered substrates, etc.)
HYDROLOGY	-Duration and frequency of inundation -Physical habitat -Water quality and availability	Favorable (i.e., minor alterations: some change in course and concentration) Unfavorable (i.e., permanently and severely altered: channelization, damming, water harvesting)
LEVEL OF DISTURBANCE	-Ecosystem functions -Soil processes -Colonization processes -Hydrology -Topography	Favorable (i.e., minor alterations: soil intact, natural colonization dominates, hydrology unaltered, etc.) Unfavorable (i.e., severe alterations: removal of all vegetation and soil, redirection of water, etc.)
ANTHROPOGENIC PERTURBATIONS	-Interferes with colonization and survival -Shifts to disturbance related species -Soil compaction	Favorable (i.e., low level and/or infrequent disturbance such as rare pedestrian traffic, periodic grazing) Unfavorable (i.e., high level and/or frequent disturbance such as regular grazing, off-road vehicle use area, heavily-traveled trail)

Table 2.2: Factors that influence rehabilitation potential (continued).

FACTOR	INFLUENCE	RANGE OF INFLUENCE
SIZE OF DISTURBANCE AND PROXIMITY OF INTACT, COMPARABLE ECOSYSTEM	-Proximity to propagules, colonizers, pollinators -Need to manually re-introduce all trophic levels	Favorable (i.e., small disturbance and proximity to refugia) Unfavorable (i.e., large disturbance and distant to refugia, or refugia absent)
NATURAL RESILIENCE	-Ability of the system to recover from disturbance -Rate of colonization	Favorable (i.e., high degree of resiliency with frequent natural perturbations such as associated with dunes and streams) Unfavorable (i.e., low degree of resiliency with infrequent natural perturbations such as associated with old-growth forests and desert scrubs)
LIFE CYCLES	-Time needed for invasion, reproduction, and colonization	Favorable (i.e., short life cycles) Unfavorable (i.e., long life cycles)
SUCCESSION	-Time needed to achieve target system	Favorable (i.e., non-successional system or system in arrested early successional stage such as a riparian scour zone) Unfavorable (i.e., climax system such as an old-growth forest)
INVASIVE EXOTICS	-Competition for space, water, and light -Survival of desired species -Rate of colonization	Favorable (i.e., few or no invasive species on-site or in the general vicinity) Unfavorable (i.e., proximity and large quantity of invasive species known to out-compete the desired natives)
WATERSHED PROCESSES	-Externally controlling environmental factors -Hydrology and water quality -Sediment transport -Geo morphology	Favorable (i.e., minor alterations: unaltered hydrology, erosion and sediment transport at normal levels) Unfavorable (i.e., severe alterations: damming, channelization of streams, increased erosion, increased and concentrated runoff, contaminants and toxic compounds)
TIME REQUIRED TO ATTAIN TARGET SYSTEM	-The number of stochastic events (natural and anthropogenic) system in process of rehabilitation is exposed to.	Favorable (i.e., small amount of time such as 20 years) Unfavorable (i.e., large amount of time such as 300 years)

3.0 SOILS AND SOIL MANAGEMENT

Soil is the foundation on which a rehabilitation project is built. In order for a site to be successfully revegetated, the soils must be able to provide the plant community with adequate rooting volume, water and nutrients, and soil biological activity. This support must occur both in the short term, to achieve plant establishment, and in the long term, if the regenerated plant community is to persist. A failure in the soil system is likely to cause a corresponding failure of the revegetation project. Therefore, a project manager must understand the physical, chemical, and biological characteristics of the soil at the project site in order to create a successful rehabilitation plan.

Each of the horizons in a generalized soil profile (Figure 3.1) contributes something to the soil's ability to support plant cover. However, these horizons and their functions are often missing in drastically disturbed soils, that is, soils from which most of the topsoil has been altered, buried or removed (Box 1978). The goal of soil regeneration activities is to help the soil (or soil-like substrate) provide enough of the required functions that plants can colonize the site, protect it from further erosion, and persist as a community.

More detailed information is available through several excellent and very readable books on the topic: *Practical Handbook of Disturbed Land Revegetation* by Frank Munshower (1994, Lewis Press); *Reclamation of Drastically Disturbed Lands* edited by R.I. Barnhisel, R.G. Darmody, and W.L. Daniels (2000, Soil Science Society of America, Agronomy Monograph 41.); *Reclaiming Mine Soils and Overburden in the Western United States: Analytic Parameters and Procedures*, edited by R.D. Williams and G.E. Schuman (1987, Soil and Water Conservation Society); and a general soils text, *Soils, An Introduction* by M.J. Singer and D.N. Munns (2002, Prentice Hall). Although we attempt to be as factual and specific as possible in this manual, the variable and extreme conditions on many mined materials often make generalizations difficult. The information presented here is held to be generally true, but potential treatments should be tested first on small field plots before being applied to larger areas.

3.1 What is a Soil?

This section reviews the typical pattern of soil layers, or horizons, found in natural soils. Each of these horizons and a few of their characteristics will be considered briefly, starting with the surface layer.

The uppermost organic, or duff, layer (O horizon) is formed from accumulated plant litter. This layer, if it exists, insulates the soil from excessive heat or cold and protects the fine-textured soil particles from the impact of raindrops, which can pelt and erode the bare soil surface. Decaying plant and animal matter creates humus, which provides a rich source of nutrients that are slowly released for sustained plant growth.

As the litter decomposes, nutrients and organic matter tend to accumulate in the topsoil (A horizon). Seeds, fungi, bacteria and small soil invertebrates are also abundant in the A layer. Healthy topsoil is rich in organic matter and biological activity and, for this reason, often has a crumb-like or granular structure rather than being powdery or dense. This open, crumb-like structure allows water to infiltrate into the soil rather than run off over the surface. Thus, the topsoil (or a topsoil-like substrate) is essential for successful revegetation. Recreating this material from basic components can be an intensive and expensive process, however. After all, the natural process of topsoil formation takes thousands of years to produce a mature topsoil, so a degraded site cannot be expected to completely regenerate itself within the short duration of a revegetation project.

As water percolates into the A horizon, it slowly leaches minerals out of the soil matrix and carries them down to the B horizon. This movement, and the higher subsurface moisture content, often causes the B horizon to be enriched in clays. Clays hold much more plant-available water than sands or silts, a critical factor on dry revegetation sites. On the negative side, a clay layer can become so dense that root penetration is difficult. In addition, salts and toxic metals may accumulate in the B horizon. The boundary between the A and B horizons can often be identified by a color change in the profile. Because the A horizon has the greatest concentration of organic matter and the B horizon has more clays or salts, the boundary between the two horizons is often where the darker, browner color of the A horizon changes into the lighter, grayer or redder B horizon. In older soils, the B horizon has more well developed soil structure and may appear chunkier than the more granular A horizon. On sites where the A horizon has been lost, the B horizon would be the next best choice for creating a topsoil, unless it is extremely clayey or salty.

The C horizon represents the underlying substrate, or parent material, that is starting to transform into soil materials, but is not very far along in the process. Subsurface horizons commonly do not support plant growth well because they are excessively coarse or fine textured or have low levels of plant-available nutrients. Materials similar to the C horizon are typical of the overburden and commodity material exposed at many mine sites.

Because the geography of California is quite variable, the soil resources at rehabilitation sites around the state also vary considerably in their conditions. A trained soil scientist can provide information on the quality and depth of topsoil on the site. Another valuable resource is the soil survey, produced for many counties of California by the United States Natural Resources Conservation Service. These data will give the practitioner an idea of the depth, quality, and chemistry of the site's original soil mantle. Of course, taking a shovel (tile spade) out to the site and digging soil pits in representative areas can also yield a wealth of information, especially where soils have been disturbed or altered from those originally mapped. Rehabilitation projects can be adversely affected by buried gravel or sand layers (Alpert et al. 1999) or buried layers of high salinity (Bertin Anderson pers. comm.) that were not evident based on surface soil inspection.

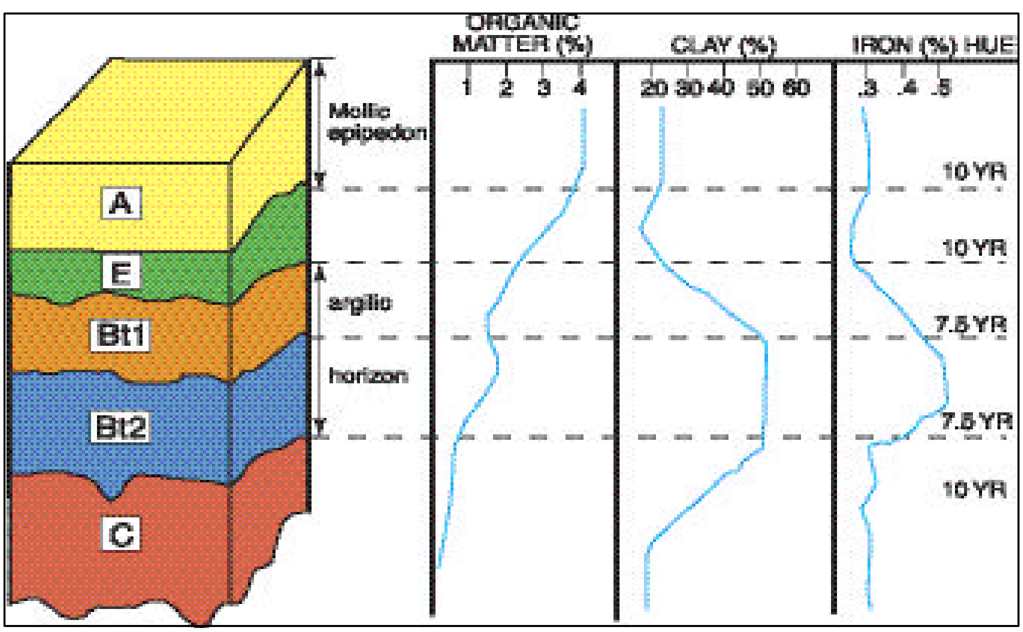


Figure 3.1: A soil profile with organic matter accumulating in the A horizon, and clay and iron accumulating in the B horizon (Singer and Munns 1999).

Once on the site, the project manager should evaluate the general landscape of the area and interpret signs of watershed processes. Is the revegetated site in a low-lying area and will it be flooded or receive sediments or salts from nearby hills? Is the site on a hillslope from which materials will be lost by erosion? Are the soils and subsoil materials transported from other places (floodplains, old dune deposits), introducing the soil characteristics of those places? Or are they derived from the geological materials underneath the site, with physical and chemical characteristics of the local area? These long-term, landscape scale trends will continue in the future, and the rehabilitation project should be designed with them in mind.

When the general terrain of the site is established, the next focus of the rehabilitation process is to consider the physical characteristics (texture, compaction), the chemical characteristics (nutrients and toxins), and the biological components (organic matter content and biological activity) of whatever substrates remain on the site and are to be used as growth media.

3.2 Physical Characteristics

The three most important physical characteristics to consider in a impacted soil are texture, aggregation (organic content), and the level of compaction. The soil texture and aggregate structure determine to a large extent the amount of water and nutrients the soil will hold. Compressibility (or the susceptibility of a soil to compaction), which is somewhat determined by soil texture and organic content, can have a long-term negative effect on a rehabilitation project.

3.2.1 PARTICLE SIZE AND TEXTURE

A typical natural soil contains about half pore space and half solid material (Figure 3.2.1a). The pore space can be occupied by either air or water, depending on the moisture content of the soil. The solid material is divided into particles that are greater than 2 mm in diameter, such as gravels or stones (the coarse fraction) or particles less than 2 mm in diameter (the fine soil fraction, or fines). The coarse fraction is usually disregarded in analyses of soil chemistry and fertility because it has a very low surface area and does not contribute substantially to the function of the soil. In many mined materials, however, the coarse fraction can be 50 to even 80% of the total soil volume. When the coarse fraction occupies a large percentage of the total soil volume, it can dilute the fertility of the whole soil profile. On the positive side, rocky soils can increase the "effective precipitation" by concentrating moisture in the fine soil fraction between the impermeable rock fragments, and the stony cover may be more resistant to erosion.

The fine soil fraction (< 2 mm) is made up of sand, silt, and clay-sized particles as well as small amounts of humus and plant and animal debris. Size fraction of soil particles are listed in Table 3.2.1. The relative proportion of sand to silt to clay-sized particles determines the soil property known as texture (Figure 3.2.1b). Sandy textured soils, for example, have percent sand content greater than 45 to 50%. Clay soils have greater than 40% clay. Loamy soils have approximately equal proportions of sand and silt, with smaller amounts of clay. The particle size distribution of the mineral particles in the soil is the primary determinant of soil texture and water release curves (the rate at which a soil will provide plant-available water) in an altered soil.

Many times the exact classification of the soil is not as important as a quick judgment on whether the soil is fine textured (and, thus, susceptible to compaction) or whether it is coarse textured (and, thus, droughty and unable to hold water). With a little practice, soil can be textured by hand (Figure 3.2.1c). Several points need to be made regarding soil texturing by hand. First, don't work soil with the hand that you will need to write notes with or that you will need to have clean for any other purpose. Second, start with a golf ball sized volume of soil, wet it, and be prepared to work it (knead, squeeze) for 10 or even 20 minutes. Keep the soil ball moist. A small squirt bottle of water is useful to add drops of water to rewet the soil as it is worked

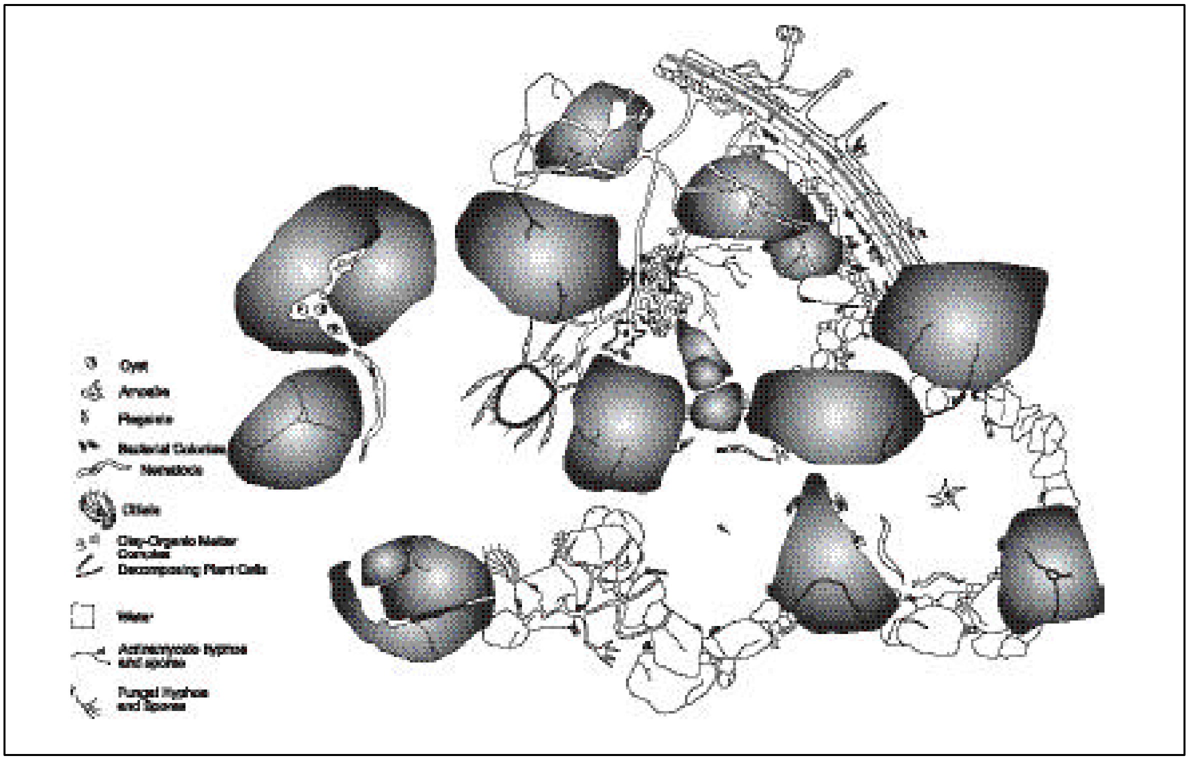


Figure 3.2.1a: Soil particles and organisms, showing aggregated particles and voids (Rose and Elliot from Coleman 1985, used with permission).

in your hand. Some of the clay aggregates take a long time to wet up and fall apart. They feel like small sand grains so they must be broken down to distinguish them from actual, sand-sized particles.

After the soil has been well worked, the sands will feel gritty and the silts will feel smooth and supple. High clay soils will feel sticky and form ribbons several centimeters long between the thumb and forefinger when damp. Very clayey, moldable soils are a warning sign of potential for compaction and cracking problems later. If the soil won't form a ribbon, squeeze a handful in your fist to form a "cast." Loamy soils will deform, or dent, under soft finger pressure while casts of sandy soils will fall completely apart when the cast is poked with the finger. A soil with a ideal, loamy texture feels somewhat gritty and forms a soil cast that does not break when poked, but also does not form the long, moldable ribbons that indicate high clay content. A soil texture with fairly high amounts of clay and also with the gritty feel of sands is an indication of a serious potential compaction problem. When soils with this texture are worked wet, these two particle sizes pack tightly together. Then, when the soil dries it develops the hard, dense consistency of a natural adobe brick.

FRACTION	DIAMETER (mm)
Sand	2.00 to 0.05
Very Coarse	2.00 to 1.00
Coarse	1.00 to 0.50
Medium	0.50 to 0.25
Fine	0.25 to 0.10
Very Fine	0.10 to 0.05
Silt	0.05 to 0.002
Coarse	0.05 to 0.02
Medium	0.02 to 0.01
Fine	0.01 to 0.002
Clay	< 0.002
Coarse	0.002 to 0.0002
Fine	<0.0002

Table 3.2.1: Particle size categories.

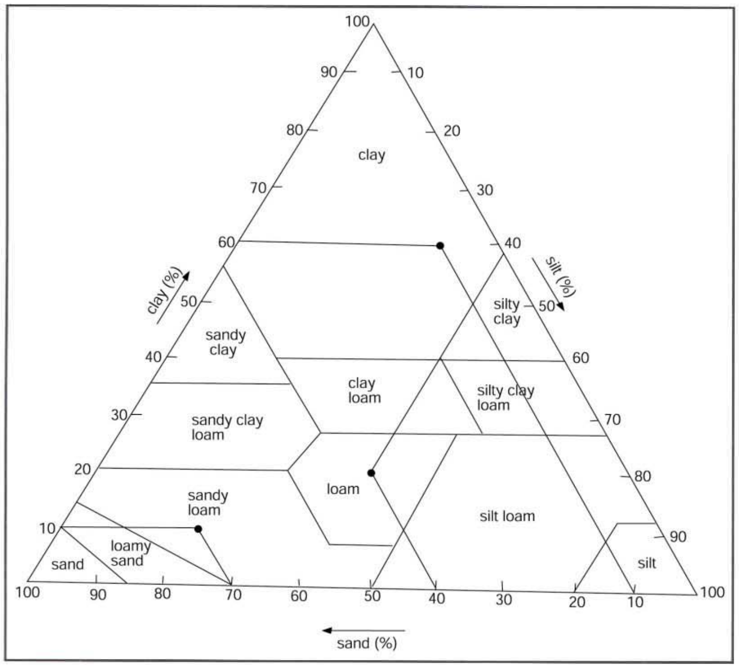


Figure 3.2.1b: Textural triangle.

3.2.2 PORE SIZE DISTRIBUTION AND WATER HOLDING CAPACITY

The soil's texture partially determines the size distribution of soil pores, which are the primary influence on water infiltration and retention characteristics. A range of sizes of pores is important because different pore sizes have different influences on water availability (Table 3.2.2). The largest pores (> 100 µm, about twice the width of a human hair) are those that will allow the rapid infiltration of rain. Water will drain out of these pores as it is absorbed into the soil, allowing air to flow in and out of the soil for root, microbial and animal respiration. Smaller pores (10 µm to 0.1 µm) are so small that gravity cannot pull the water out of them. These pores hold water for plants to draw in through their roots to replace water transpired from their leaves. These pores also form the passages within which soil bacteria and fungi move, digesting dead plant materials and releasing their nutrients for plant uptake. The smallest pores (< 0.1 µm) hold water so tightly that it is difficult for many plants to extract water from them. A soil with a compacted surface may potentially be able to hold significant amounts of water, but the rate of infiltration into the surface is so slow that rainwater runs off the surface and the soil beneath the surface may stay dry.

3.2.3 COMPACTION

Natural soils typically have an open pore structure in which the particles are not closely packed. The pore space of a structured soil allows air to diffuse in and out and allows water to infiltrate quickly. The particles are held in an open, porous pattern by organic matter, roots and fungal hyphae. When soils are moved, driven on, excavated or otherwise handled when wet, the particles become closely packed and the soil becomes compacted. Compaction decreases soil aeration, reduces the ability of the soil to hold and release water, creates a higher fluctuation in soil temperatures, and increases the difficulty of root penetration. After the soil has been compacted, precipitation is more likely to run overland and off the site rather than to percolate through the soil, resulting in increased surface erosion and less moisture available to plants. All these changes caused by compaction negatively affect plant growth and survival, and this one factor, compaction, can result in the failure of an otherwise well-executed rehabilitation plan.

Webb et al. (1988) found that compacted soils may persist in a desert setting for over 100 years and that vegetation patterns reflect the soil compaction patterns. Newton (unpubl. data) demonstrated on a wetland site that the level of compaction significantly affected the resulting recovery and vigor of the wetland vegetation, and Froehlich and McNabb (1984) demonstrated that compaction reduced stand productivity for at least three decades in Pacific Northwest forests.

Soils with high organic matter content are less susceptible to compaction because organic matter holds the soil particles apart so that they don't pack

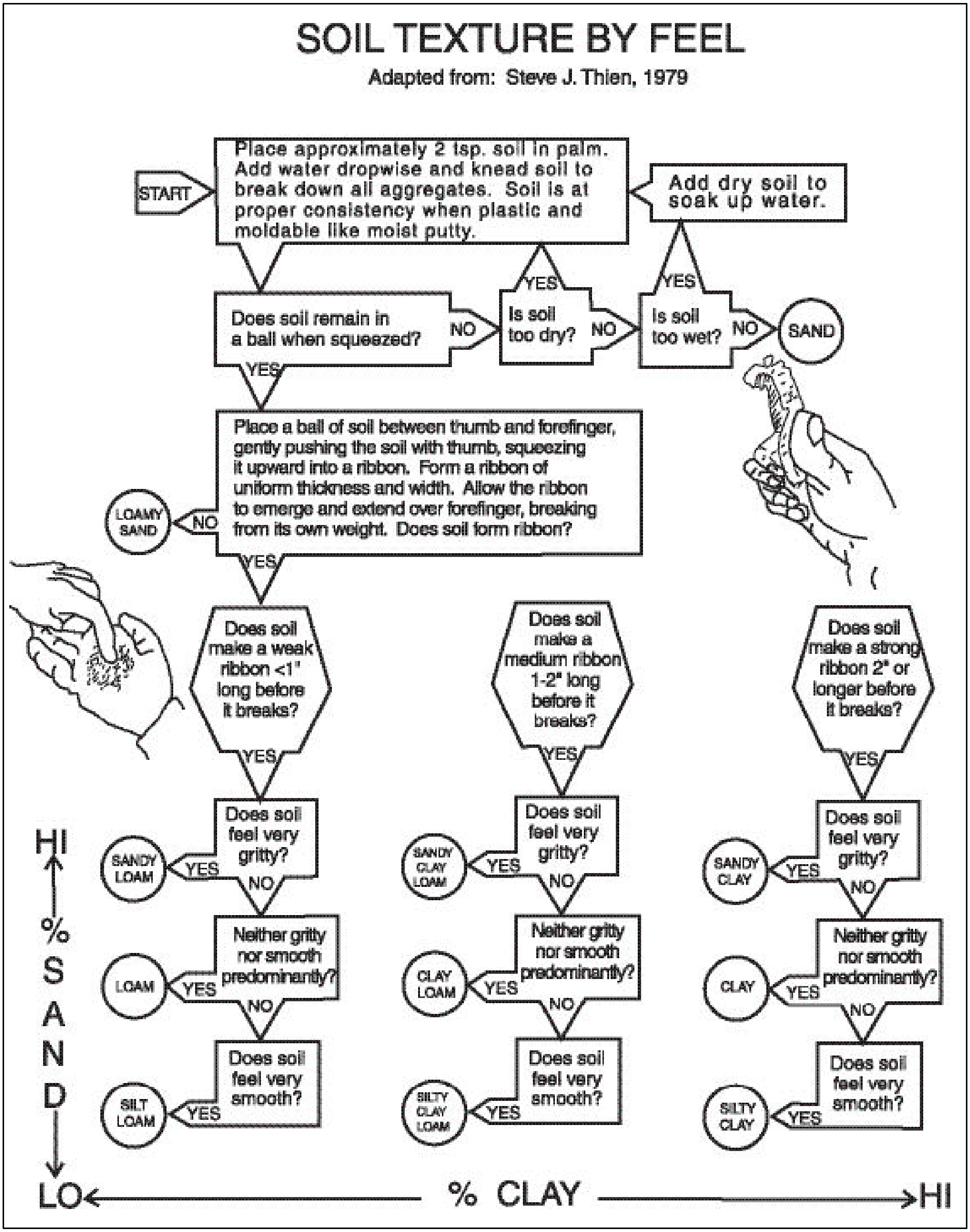


Figure 3.2.1c: Determining soil texture by hand. Used with permission of the Soil Science Society of America and Agronomy Society of America.

and adhere so tightly together. Soils with low organic matter content or high sand and clay content are especially susceptible to compaction, since even small amounts of clay can tightly pack between the solid sand grains and bind the soil tightly together. Tillage or deep ripping of a compacted soil will open up cracks in the soil profile, but without further development of soil structure these ripped soils will often settle and repack within a year or two. Calcium or organic matter can help start the process of soil structure development.

The natural rate of loosening of compacted soils is determined by the level and depth of compaction, the overall texture, the amount of clay in the soil, the amount and depth of water penetration, the level and type of biological activity, and the climate (freeze-thaw cycles and wet-dry cycles). Depth and extent of compaction will increase if the soil is disturbed while wet (Voorhees et al. 1986). Thus, wetland soils, which are wet and high in clay, will remain compacted for decades after compaction and cannot be loosened because they never adequately dry out.

Some compacted soils can be partially loosened by deep mechanical ripping while the soil is dry (Steed et al. 1987, Bainbridge 1993), and should be done without inverting the soil horizons. A ripper (vertical shanks two to seven feet long), chisel plow, mold-board plow, or 32- inch disk can be used to decompact compacted soils. Ripping should be done in more than one direction, with the last pass being on the contour of the slope. The more common attempts with a smaller disk, rototiller, or standard plow usually fail to adequately loosen the soil below the top few inches. However, the best method for addressing compaction on a site is avoidance, i.e., take measures not to compact the soil in the first place. Several measures can be taken to minimize or avoid compaction:

- work soils when dry through the whole profile,
- keep people and vehicles off or minimize the number of trips,
- use equipment with oversized (flotation) tires, which disperse the weight over a larger area,
- use lighter equipment that will place less weight on the soil, and
- add organic matter to soils while working or moving them.

Scale	Particles	Aggregates	Pore Function	Biota	Scale
10^{0} (meter)	Boulders			Humans	10^{0} (meter)
10^{-1}	Stones	Clods		Rodents	10^{-1}
10^{-2}	Gravel		Fast drainage (Aeration)	Invertebrates	10^{-2}
10^{-3} (mm)	Sand	Macro-aggregates	Macropores	Roots	10^{-3} (mm)
10^{-4}		Micro-aggregates	$\psi < -0.01$ MPa		10^{-4}
10^{-5}	Silt	Domains	Plant available water	Mycorrhizal fungi	10^{-5}
10^{-6} (µm)	Clay			Fungi, Bacteria	10^{-6} (µm)
10^{-7}	Colloids		$\psi > -1.5$ MPa		10^{-7}
10^{-8}	Molecules	Clay laminae	Interlayer water	Viruses, Humic Subst	10^{-8}
10^{-9} (nm)				Organic Molecules	10^{-9} (nm)
10^{-10} (A)	Atoms				10^{-10} (A)

Table 3.2.2: Scale and function in soils (redrawn from Waters and Oades 1991). By permission of The Royal Society of Chemistry.

MEASURING COMPACTION

Soil compaction is usually measured by two different methods, either through bulk density or through a penetrometer test. Bulk density is expressed as the dry weight of soil per unit area (e.g., grams/cm^3). A known volume of soil (core sample) is taken carefully (without further compacting the soil) and dried at 100-110°F for one week, or until no additional weight loss (by water) is noted. This volume is then weighed, resulting in a figure, such as grams/cm^3, which can be compared to a similarly treated sample from an undisturbed site to determine the level of compaction at a desired depth of soil. Bulk density in a coarse-textured soil will be higher than in a fine-textured soil because the coarse-textured soil will have a less overall pore space (at comparable compactions). The bulk density of a soil is determined mainly by the mineral fraction of the soil; therefore, organic matter, which holds the fine soil particles apart, will lower the bulk density by maintaining open space in the core sample. Typical bulk density values (uncompacted) range from less than 1.0 g/cm3 for clay soils to 1.6 g/cm3 for sandy soils.

A penetrometer test involves pressing a spring loaded probe into the soil or hammering in a metal bar and measuring the resistance or the number of impacts, or hits, needed to penetrate the soil. The more resistance or hits, the greater the level of compaction. The results of this method only have a meaning if compared to an undisturbed site. Penetrometers are now commonly sold through forestry, engineering, and soil equipment suppliers. Be sure to distinguish between a high reading caused by a truly impenetrable soil versus a buried rock fragment.

3.2.4 PHYSICAL EFFECTS AND AGGREGATION RESULTING FROM SOIL ORGANIC MATTER

Soil organic matter decreases compaction and bulk density because it is less dense than mineral matter and because it holds the fine mineral particles in an open, porous structure. This open structure allows water and air movement in the soil, it allows microbes to live in water-filled pores, and it reduces heat transfer through the soil, thereby reducing heating and freezing problems. For all these reasons, soil organic matter is critical to soil functioning, even though it is not itself classified as an essential plant nutrient (Smith et al. 1987).

Soil organic matter has the beneficial aspect of binding small clay or silt sized particles together into larger aggregates that are the size of sand particles (Figure 3.2.4). In doing so, soil organic matter can gradually transform a densely packed, impermeable soil material into a porous, well-aerated, plant growth medium with improved resistance to erosion. Smaller, micro-aggregates (< 250 µm) tend to be bound by humic substances, decomposed bacterial cell wall residues, and metal oxides. These materials are very slow to decompose and can persist in soils for decades (Parton et al. 1988, Tisdall and Oades 1982). Stockpiling of topsoil materials will cause only small decreases in humified types of soil organic matter.

Larger macro-aggregates (> 250 µm), in contrast, tend to be bound by microbial colonies and tied together by fine roots and fungi (Figure 3.2.4). Even short periods without energy inputs from plant growth cause rapid decline in macroaggregate structure. Perry and Amaranthus (1990) describe a highly productive timber-producing site on granitic soil in southern Oregon. After clearcutting, the site was herbicided several times to reduce brush invasion. The resulting loss of organic matter input from plant growth caused the soil to lose its structure, its water holding capacity, and its soil organic matter and fertility. This formerly productive forest soil subsequently supported only scattered annual grasses, ferns, and an occasional manzanita.

The addition of organic matter such as composts or chipped green waste to a disturbed soil may provide some of the benefits of native soil organic matter. Yard waste composts have been shown to provide modest, steady releases of nitrogen (N) for plant establishment (Claassen 1999). Because these

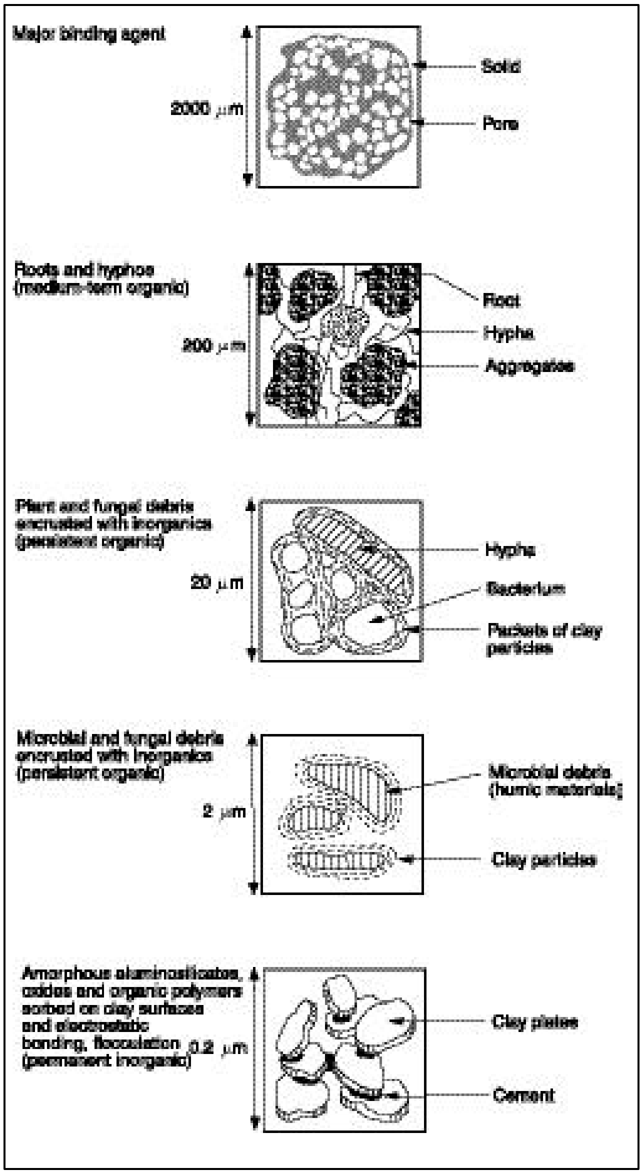


Figure 3.2.4: Hierarchy of water stable aggregates (soil structure). Tisdall and Oades 1982.

materials vary widely between producers, not all composts will behave the same in field conditions. Uncured composts, for example, may not release sufficient N for plant growth and may need additional N inputs. Municipal biosolids materials have much greater capacity to release N to the soil and should be blended with yardwaste composts or other low-N materials to reduce the N-release rates.

Topsoil remains the ideal source of soil organic matter. The organic pools in soils have accumulated for hundreds to thousands of years and are usually excellent growth media. The high levels of humic materials will decrease only slightly in stockpiles, even though the levels of easily decomposed organics will decline within a few seasons. Nevertheless, topsoil should be stockpiled from the site before disturbance if at all possible, or it should be direct-hauled from an expanding area of a mine to an area undergoing revegetation. Commercially available synthetic polymers (PAM products) can act as temporary glues to hold particles together in their current orientation, but they only last a few seasons and do not generate microaggregate structure where there was none initially.

3.2.5 COARSE FRAGMENTS

The fine soil fraction (< 2 mm) that provides the majority of the nutrient and moisture retention capacity of a soil can be significantly diluted by the presence of inert coarse fragment materials (rocks). These include gravels (0.2-7.6 cm), cobbles (to 25 cm), stones (to 60 cm), and boulders (greater than 60 cm). While they dilute the soil needed for root growth, they can have some positive benefits. Rock mulches can reduce surface erosion and reduce compaction from wheeled traffic. In arid areas, the reduction of water holding capacity can be offset by the penetration of rainwater to deeper soil horizons where it is less susceptible to evaporation. Species diversity can also be greater on rocky soils (Redente et al. 1984). A compilation of rock fragment suitability studies puts the limit of “good” or “suitable” material for soil substitutes at about 15% rock fragment content of the soil volume or less (Munn et al. 1987).

3.3 Chemical Characteristics

The performance of plant materials on the site is strongly influenced by the soil’s chemical characteristics. Most chemical characteristics are analyzed by short-term lab extractions of the soil, followed by analysis of the nutrients or metals in the extraction solution. Procedures at each of these steps can greatly influence the results of the analysis, so it is important to know what methods are used to get the soil test results and how they should be interpreted. Assistance from an experienced soil scientist is usually required.

A useful technique is to compare the results from samples of an impacted area that is to be revegetated with results from a vegetated reference area, usually one that has been disturbed but that supports adequate vegetation. Comparison with native, undisturbed soils can indicate higher soil nutrients levels than are readily attainable on degraded soil revegetation plots, although they give good information on long-term soil development. Soil chemistry is highly variable over small distances, so replicated samples (four or more per substrate type) are needed to get a complete picture of the soil chemical condition.

3.3.1 ACIDITY AND ALKALINITY (pH)

Soil reaction (acidity or alkalinity) is measured by pH. Soil pH is an important soil parameter because it influences nutrient and micronutrient availability and because it indicates whether the soil reaction (acid or base level) is generally adequate for biological activity (Tucker et al. 1987).

Many soil chemical reactions and biological activities are optimum for plant growth when the pH is between pH 6 and 7. Higher soil pH levels often reduce nutrient availability through a number of mechanisms. Nitrogen fixation, nitrification and soil protein hydrolysis declines at pH levels over approximately 8.5. Phosphorus (P) availability declines at high pH because P precipitates with carbonate minerals. Liming with an alkalizing agent can reduce toxic levels of many metals; excessive liming, however, may cause precipitation and nutrient deficiency of iron, zinc and copper. Boron (B) and molybdenum (Mo) availability, however, increases with alkalinity. Soil pH levels above 8.5 indicate the presence of excessive sodium (Na) and its associated effects of crusting and soil dispersion.

Lower soil pH levels (acidic conditions) decrease root growth and also can lower nutrient availability. Below pH 4.8, aluminum becomes soluble in the soil solution, where it binds with root meristems and stops growth (Lindsay 1979, Foy 1974). Microbial activity generally decreases below pH 6, reducing the rapid cycling of N, P and sulfur (S) via plant residue decomposition. Below pH 5.5, fungi predominate in the decomposition process while bacteria and actinomycetes are more active above pH 6.0 (Kamprath and Foy 1971). Mineralization of soluble organic matter to form free ammonium is relatively pH independent, but the conversion of ammonia to nitrate declines below pH 6, with decreasing levels of conversion down to pH 4. Sensitivity of nitrogen fixation depends on the plant and bacterial species, but rates of fixation decline below pH 5. Plant available phosphorus declines below pH 6 as soil organic matter mineralization slows and as P becomes precipitated into iron and aluminum phosphates. However, on unweathered granites, P availability increases with acidity because the apatite dissolves from the rock matrix (Claassen and Zasoski 1996). Acid soils can have toxic solution concentrations of aluminum and manganese. Plant species vary in their tolerance to soil acidity, with several cool season grasses having a reported lower limit of pH 4.5 to 5.0. Warm season grasses are reported to have a lower pH limit of 4.0 to 4.5 (Vogel 1981). In the western United States, the critical lower level seems to be about 5.0 and 5.5. Soil organic material in the soil allows plants to tolerate lower soil pH levels before toxicity occurs (Foy 1974).

Measurement of soil pH that most closely represents the acidity that a root experiences is achieved by using a saturated paste sample. A saturated paste is typically formed from a 2:1 soil to water ratio (Sobek et al. 1978), but should be adjusted until the soil surface barely glistens with free standing water, a pH electrode is then immersed in the sample. While this gives the most accurate representation of soil reaction, a practical consideration is that immersing a pH electrode into a gritty or gravelly sample can easily scratch and damage the sensing electrode's glass surface. Although a 1:2 soil to water ratio generally gives higher pH readings (less acid), it allows the soil solution pH to be measured without scratching the electrode. Another measurement concern is that the salt content of the solution can alter the pH reading. A method of standardizing the salt content of the soil solution is to use a standard 0.01 M $CaCl_2$ solution to wet up the sample for pH analysis.

The pH measurement described above can indicate overall acid generation problems and the possibility of plant growth problems. This "instantaneous" acidity, however, is not useful for estimating the total amount of acidity in a mined material, the potential to generate acidity in the future, or the amount of lime needed to neutralize it. Such short-term tests of acid content do not account for the potential for sulfides in the soil to oxidize and produce additional acidity. Several methods are available for estimating lime requirement, including titration (Sobek et al. 1976), several buffer methods (Shoemaker, McLean, and Pratt 1962, Sobek et al. 1976), peroxide treatment, and analysis of total sulfur after sulfate removal (Smith et al. 1976) or by long-term empirical bench-scale incubation.

Lime application rates are usually given in parts per thousand, or tons of lime per thousand tons soil material. Calcium carbonate ($CaCO_3$) is commonly used as the source of alkalinity, either from ground limestone or from high lime content agricultural or industrial wastes. Calcium hydroxide ($Ca(OH)_2$) or calcium oxide (CaO) are other more potent sources of alkalinity. These two materials must be used carefully because they may burn the roots if applied excessively or unevenly. When applied several months to a season ahead of planting, the lime will have time to react so that plant roots are not damaged, if the soil is moist. Use caution to avoid exposure of the planting crew to caustic amendments.

All the lime materials must be finely ground (less than 50 mesh, or 300 µm). In an acid soil, larger particles become sealed with coatings of metal precipitates and may not react completely with the soil. Lime materials migrate very slowly within the profile, so they should be incorporated to the desired depth. If the soil cannot be mixed by surface tillage, lime can be incorporated during the last several lifts of earthwork fill using heavy equipment. Examples of lime application rates for existing abandoned mine sites in California are included in Table 3.3.1.

ACID ROCK DRAINAGE

Soil pH can also indicate whether the mined material has produced acid rock drainage (ARD). ARD results from the oxidation and hydrolysis of sulfide mineral deposits in the mined material. When buried deep underground in anoxic conditions, the rate of oxidation is slow or non-existent, but when exposed at the earth's surface, the sulfides (often pyrite, FeS_2) oxidize in the moist, oxygen-rich environment and form sulfuric acid. The iron component of the pyrite also hydrolyses and creates additional acidity. Soil bacteria of the genus *Thiobacillis* are common in sufide-rich substates. With moisture and oxygen, these organisms can accelerate sulfur and iron oxidation reactions up to a million times faster than the inorganic reaction rates and can show optimum growth rates at pH 2 to 3 (Nordstrom 1982). The increasing acidity often dissolves aluminum from local minerals, which can generate even more acidity through hydrolysis, forming a continuing cycle of acid generation. Minerals such as jarosite are formed under acid conditions and are unstable when the pH is increased by liming. As these unstable minerals decompose, they can reacidify the mined material.

3.3.2 CATION EXCHANGE CAPACITY (CEC)

Retention of cation nutrients is an important function of soil and is evaluated by measuring the cation exchange capacity. The cation exchange capacity (CEC) is the negative charge on minerals that holds cations against leaching losses and retains cations that weather out of minerals, keeping them available for plant use. Nutrient cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), ammonium (NH^{4+}), or potassium (K^+) are retained by ionic exchange between these positively charged cations and negatively charged soil materials

(Figure 3.3.2). Several non-nutrient cations (sodium (Na^+), hydrogen (H^+), or aluminum (Al^{3+}) also are retained by the CEC. Acid soils often have low nutrient fertility because hydrogen and aluminum displace nutrient cations from the CEC and contribute to nutrient loss from acid soils. Alkaline soils may accumulate enough Na^+ on the CEC to interfere with K^+ uptake.

Pure clays or soil organic matter can have CEC levels in the range of several hundred centimols of charge per kilogram (cmol kg^{-1}) soil. However, these materials are in relatively low concentrations in soil, so total soil CEC levels are often only between 10 and 30 cmol kg^{-1}, even in good agricultural soils. Lower CEC levels indicate coarse soils or low charge capacity clays that will have poor ability to hold nutrient cations. Application or accumulation of well composted organics can also increase the soil's CEC.

The portion of the CEC that is generated by substitution of aluminum for silica in the clay mineral is called "permanent charge." The portion of CEC generated by negative charges on the organic matter and by metal oxides is called "pH dependent charge" or "variable charge" because it increases as pH increases. As an acid soil is limed, the variable charge CEC increases and is able to sequester greater amounts of cations than when the soil was still acid. The practical application is that an acid soil, whose CEC is measured at neutral pHs, will indicate much more CEC during lab analysis than actually exists in the field conditions.

Soils can also have an anion exchange capacity resulting from positively charged mineral surfaces attracting negatively charged anions. Plant nutrients that are anions in the soil include phosphate (PO_4^{2-}), sulfate (SO_4^{2-}), and molybdenum (MoO_4^{2-}). These anions may also be retained by cationic bridging, in which a nutrient anion is ionically attracted to a cation such as Ca^{2+}, which, in turn, is bonded to a negatively charged soil surface. Calcium application to acid leached soil increases ionic bridging between soil minerals and nutrient anions.

3.3.3 SALINITY

Excessive salt in soil water decreases the effective moisture available for plant growth. Salt slows growth and, by accumulating at leaf tips, can damage and "burn" tissue. Yellow, brown or black leaf tips are a visual indication of salt stress, as well as other types of stress. Arid-land plants often have adaptations for this problem, including the ability to make various internal osmotic adjustments in order to balance external salt concentrations. This effort is metabolically expensive and, along with reduced water availability, results in plants that look normal but are abnormally small for their age. The level of salinity that reduces plant growth varies widely with plant type, with some native species being far more

Mine Site	Substrate	Tons per 1,000 tons	Mg per ha (30cm)
Leviathan	pit	13	45
Sulphur Bank	overburden	9	16
	shoreline berm	25	41
Spenceville	jarosite overburden	25	97
	hematite roasts	15	58
	altered soil	10	39
Gambonini	pit slope	3	11

Table 3.3.1: Approximate liming rates for existing abandoned mine projects in California. Values are in $CaCO_3$ equivalent. Mg per ha (30 cm depth) values include correction for coarse fragment content of the substrates at each site.

tolerant of salt than the commonly studied agricultural species. Sensitivity to salt is greatest in early growth stages (Jurinak et al. 1987).

Accumulation of soluble salts in the soil can be evaluated by measuring two parameters: the salinity of the soil and the proportion of the exchange capacity that is occupied by sodium. These two parameters are important since the electrical conductivity (EC) of a soil determines the physiological effect of the soil solution on plant growth, while the sodium content indicates the potential for soil dispersion and sodium phytotoxicity.

The EC of a soil is measured on a saturated paste extract of the soil (Sobek 1976) or in the solution extracted from soil for pH measurement (Rhoades 1982). EC readings are temperature sensitive so solutions should be close to 25°C when measured (Munshower 1994). Soils with an EC measuring less than 4 (dS/m) (decisiemens per meter) are classified as non-saline for agricultural crops, but many arid lands plants can thrive at higher EC levels. The need to produce a marketable yield may account for some of the "sensitivity" of agricultural crops, whereas revegetation species do not need to produce harvestable biomass, but need only to survive and set seed. For example, beardless wild rye (*Leymus triticoides*) produced seed at soil solution ECs of 18 dS/m. A fifty percent reduction of leaf biomass did not occur until 24 dS/m for fourwing saltbush (*Atriplex canscens*) and until 36 dS/m for cuneate saltbush (*Atriplex cuneata*) (Jurinak et al. 1987).

Sodium in the soil is measured by the sodium adsorption ratio (SAR), which is the ratio of sodium to calcium plus magnesium on the exchange. Soil physical dispersion and plant water uptake become limiting at SAR values between 12 and 15. SAR values less than 11 are ranked as "adequate" (although this value may increase in low clay soils) while values greater than 15 rank "poor" (Munshower 1994). Excessive sodium in the soil may decrease potassium uptake.

$$\text{SAR}= \frac{\text{Na}}{\Sigma\,(\text{Ca} + \text{Mg}/2)}$$

Another method used is the exchangeable sodium percentage (ESP). The ESP measurement is less commonly used because the CEC must also be measured.

$$\text{ESP}= \frac{\text{Na} \times 100}{\text{Cation Exchange Capacity}}$$

Sodium problems occur at ESP values greater than 15%. Critical levels of both of these characteristics are influenced by soil texture. Adapted plants may grow suitably, even above the critical levels.

A saline soil is defined as having an EC of greater than 4 and a pH less than 8.5. Soils with both salts and high sodium are called "saline-sodic" soils and have ECs greater than 4 and ESPs greater than 15%. If these soils are leached of salts, the residual sodium will cause the pH to increase beyond 8.5, potentially even rising to pH 10. Soils

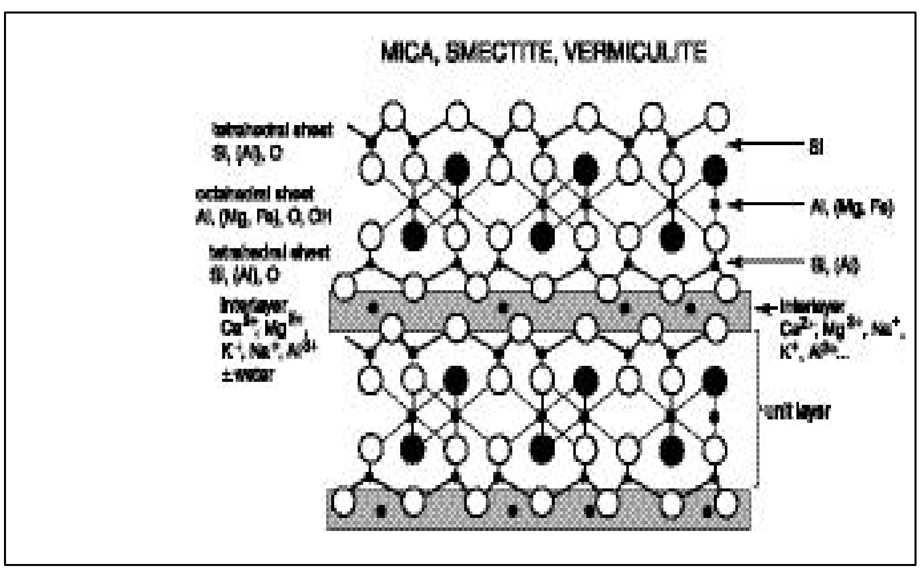


Figure 3.3.2: Generation of cation exchange capacity on clays (Singer and Munns 2002; Schulze 1989).

with ECs less than 4 are not saline, but if they have elevated sodium they are termed "sodic." The concern with sodic soils is that sodium causes soil aggregates to disintegrate, making soils susceptible to compaction and making water infiltration difficult. Calcium amendments can be used to displace sodium from the exchange complex and improve soil structure and water movement. Amendments containing calcium include gypsum or phosphogypsum (Singer and Munns 2002). Lime ($CaCO_3$) is not typically used as a source of calcium on saline or sodic soils because the soil pH is often already alkaline.

3.3.4 PLANT NUTRIENT AVAILABILITY

An agronomic pattern of plant establishment requires repeated input of nutrients, and thus a large fraction of the nutrient content in the soil is in highly available forms. Management of the agronomic plant community (spraying, mowing, and weeding) is frequent and intensive. These systems often do not persist after the inputs and management are stopped.

In contrast, revegetation schemes that adhere to a wildlands plant-soil system model should receive little or no input except for the initial remediation and amendment. The plant-soil system must, in the long term, function on its own to retain and cycle nutrients adequately. Components of the system should be selected so that management inputs can be slow or nonexistent. For natural soils, large nutrient reserves with very slow release rates are essential. For plant communities, slow but consistently growing plants, often native and perennial, demand little or no management input.

Nutrients that plants require for growth include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), in addition to carbon (C) and water (H_2O). These nutrients are required in relatively large amounts and thus are called macronutrients. A second set of essential elements is the micronutrients, which are required in much smaller amounts. These include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl) and boron (B).

The essential elements can also be categorized into groups of mobile nutrients and immobile nutrients. This characteristic is important for reclamation work because it summarizes the tendency for the element to be held in the soil by chemical and/or biological processes or to move out of the soil by leaching.

Because mined materials often have atypical, unbalanced nutrient distributions, each element will be considered individually in this discussion. The soil regeneration plan as a whole, however, must integrate the individual amendments into a nutrient cycling system that is stable in the field, provides a sustained nutrient supply for the plant community, and requires little or no additional human input. Target values for nutrient amendments can sometimes be established from existing data, but a useful strategy is to also analyze soils on adequately vegetated areas and to use those soil nutrient availability values to interpret nutrient deficiencies or excesses on the barren substrates that are to be treated.

3.3.4.1 Nitrogen (N)

The most common nutrient element deficiency in disturbed lands is N (Bradshaw 1982, Bauer et al. 1978, Munshower 1994), although in arid, calcareous soils, water or P limitations are also common. Nitrogen deficiencies are common because of several characteristics of N in soils and plants. First, N is required for plant growth in the greatest amount relative to other nutrients. Second, N occurs in several chemical forms that are easily lost from the plant-soil system. Third, this element is not typically weathered from the geological parent materials but, (see Holloway and Dahlgren 1999 and Holloway et al. 2001, for exceptions), and must usually be biologically introduced into soils that are often inherently biologically inactive. Disturbed soils commonly contain too little N to regenerate the many components of the revegetation system that require it.

Agricultural systems compensate for this N deficit by repeated amendment with fertilizers containing N, providing an additional 7 to 150 kg N/

ha/yr (Singer and Munns 2002). This N is typically in readily available forms that are taken up rapidly by crop plants and weeds or else are leached from the soil profile. Nitrogen tends to flow through the system and come out in crop yields or in drainage waters. In contrast, wildland soils, which do not typically receive supplemental fertilizers, cycle N within their soil, plant, and microbial components. The main storage location for N in temperate wildland systems is the soil organic matter. Native soils commonly contain 3,000 to 7,000 or even 10,000 kg total N/ha. The majority of this N is not available for plant uptake, but is held within soil organic matter in forms that don't leach away. While this N is not used for plant nutrition, it provides other benefits, such as development of water-stable aggregates, increased cation exchange capacity, and improved holding capacity.

On drastically disturbed sites, the N rich topsoil is often removed or buried, greatly reducing this N reserve. Soils in the Lake Tahoe Basin that have been disturbed and are now steadily revegetating contained an estimated 1200 kg total N ha^{-1} on soils that support over 40% plant cover (Claassen and Hogan 1998).

Decomposition rates of these stabilized soil organic matter pools are estimated to be approximately 3% per year (Singer and Munns 2002). If 3% of total soil organic matter N is mineralized per year, the calculated release rate is about 90 kg N/ha/yr using a 3,000 kg total N/ha figure, and approximately 36 kg N/ha using a 1200 kg total N/ha figure. Below some level of plant available N, plant cover will be insufficient to prevent erosion, further organic matter may not accumulate, and the vegetative community on the site may not persist.

Part of the reason that large amounts of N are required for revegetation of N depleted soils is that N is required for many components of the plant-soil system in addition to the above-ground plant growth that is most visible. The N required for various biologically active components of plant-soil systems of a range of grassland sites ranges from 80 to over 400 kg N/ha (Reeder and Sabey 1987). About 25% of the biologically active N is in microbial biomass, needed for cycling and decomposition of plant residues, and another 20% is retained in decomposing plant litter. About 40% is incorporated into plant roots and only about 12% of the biologically active N is in above-ground plant tissue. A second example from the *Atriplex* shrublands in the Great Basin is shown in Figure 3.3.4.1. This example shows the presence of a large pool of N in the soil (7920 kg N/ha), of which only a small proportion is taken up or denitrified per year. The biologically active pools cryptogamic crusts, plant biomass and litter (boxes c, d, e, g and l) total 529 kg N/ha.

Because several soil system components compete for N, the amount available for plant uptake at any one time is small. Many perennial plants that survive on native soils are adapted for slow N uptake. Application of higher N amounts may allow more rapidly growing weedy species to quickly colonize a site and crowd out slower growing native and/or perennial species. Because the plants usually desired for the site tend to be slower growing, less water consumptive, native, and perennial, it is critical that N availability be kept low early in the project so that the site is not overrun with fast growing weeds. Synthetic slow release chemical fertilizers and organic amendments can provide initial amounts of slowly available N, but longer term in release (several years) is a function of organic amendments. These organic materials, including composts and agricultural or biological byproducts, provide a range of additional beneficial characteristics as well as N, including increased biological activity, water holding capacity, and improved soil physical condition. The release rates of organics vary greatly and plants should be monitored closely for signs of nitrogen deficiency.

Plant N deficiency is often indicated by a general yellowing of the leaves, especially the mature lower leaves, and by unfilled seed heads. Leaves will be uniformly yellow-green (as opposed to iron deficient plants, which have yellow-green areas on the leaves with dark green areas along the veins). However, as plants mature and die they also may fade and become yellow as N is removed from the leaves and stored in roots or seeds. Yellow-green bottom leaves with darker green leaves on the top of the plant are a typical sign of N deficiency.

Plant tissue testing for N in some wildlands species has limited usefulness. Although crop plants and weedy species will respond rapidly to N availability and may have detectable variation in tissue N levels, the slower growing perennials from later seral stages may not (McLendon and Redente 1993). Slower growing perennial and native species may have growth patterns that are externally limited so that tissue N concentrations remain constant even with N amendment. Similarly, when N is deficient, the plant tissue N will not necessarily decrease. The plant may compensate for inadequate N by reducing total plant growth, thereby maintaining constant tissue N concentration.

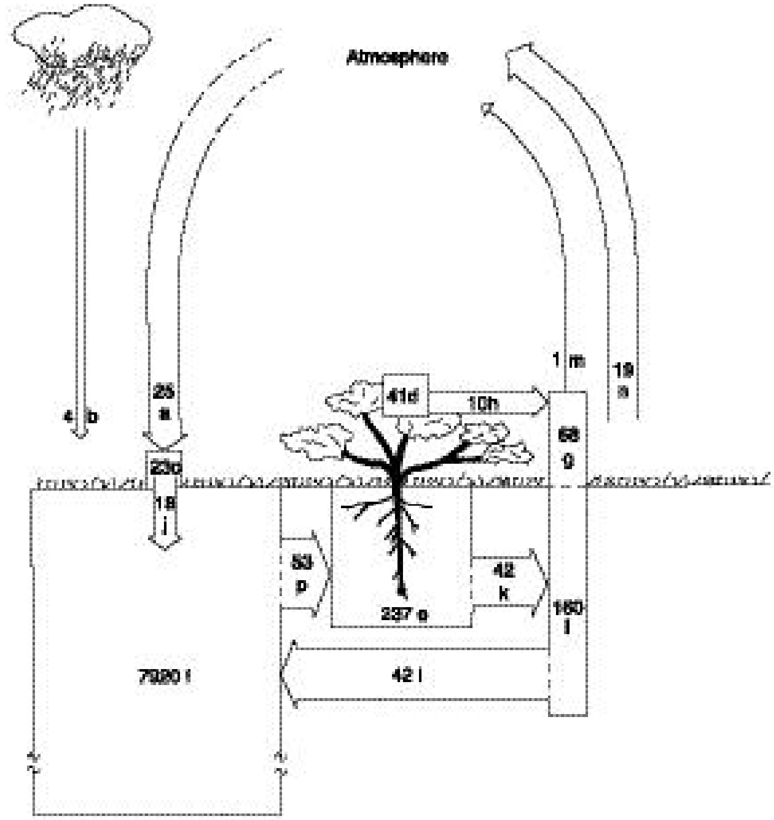
Quick release fertilizers should be avoided because the release rates are too rapid and the total amounts applied are typically too low. Commercial slow release N formulations are available but release rates should be monitored because they can change with the variable chemistry and temperature of mined materials. Municipal yard waste compost amendments of 20 to 90 Mg ha^{-1} have been used to provide baseline levels of organic matter on several Northern California mine sites, but release rates are difficult to estimate and supplemental N has sometimes been required. Long-term N release from yard waste composts has closely matched natural soil release rates.

Commercial organic- and chemical fertilizer-based soil amendments with a range of release rates are available. A combination of an inexpensive organic matter source such as composted yard waste or agricultural compost, in combination with a supplemental slow release N material, is likely to provide both the quantity and N content required for revegetation of drastically disturbed soils. The California Department of Transportation is continuing research into appropriate blends and release rates of composted materials for use on degraded sites.

3.3.4.2 Phosphorus (P)

Phosphorus (P) is used throughout the plant for energy transfers and for various cell structures. Concentrations of P in leaf tissue are less than 1/10 that of N concentrations and P is a much less mobile nutrient in the soil. The plant’s options for P acquisition are very different from the options for N. The P in disturbed soils is primarily in the inorganic (orthophosphate, HPO_4^{2-}) form. This ion binds tightly to mineral surfaces, especially at both high and low pH extremes. Because P binds tightly to the soil and moves slowly by simple diffusion, the plant cannot draw it out with the soil solution as with N. Instead, the plant root must grow to the locations in the soil where the P is held and withdraw it at that site. This pattern favors uptake by plants with fine fibrous root systems such as grasses. Non-fibrous rooted plants mimic this fine root structure by supporting beneficial mycorrhizal fungi, which grow out from the plant roots and explore the soil. The symbiotic process and types of mycorrhizal structures are discussed in more detail in the microbiology section.

Because P binds tightly to iron and aluminum oxides at low pH and to calcium carbonates at high pH, plant availability of P is very dependent on soil acidity and mineralogy. Iron rich soils will retain extremely high amounts of P that is inaccessible to plants. These soils require large amendments before the surplus, or unbound, P becomes available for plant uptake. Such soils are identified by fine texture (high surface area) and reddish, orange or yellow-brown colors. The advantage of soils with high P retention is that once the capacity of the soil to retain P has been filled, it will be slowly available for long periods of time. Sandy, unweathered, non-calcareous soils, on the other hand, retain low amounts of P. On these soils, P applications must be very conservative so that P availability does not become high enough to discourage formation of mycorrhizae. Low soil P retention means that P applications must be repeated



Schematic representation of the main aspects of the annual nitrogen balance for a Atriplex confertifolia-dominated ecosystem in Curlew Valley, Utah. Arrows are fluxes (kg N/ha per year). Width of arrows approximates the magnitude given in numbers inside arrows. Boxes represent the highest annual values of the components (kg N/ha). Average of 3 or more years' data. Sources of data itemized in West and Skujins (1997). a = biological fixation, mainly by blue-green algae in cryptogamic crust; b = input in wet and dry precipitation (including dust); c = total N in cryptogamic crust; d = total N content of above-ground higher plant biomass; e = total N content of living below-ground higher plant biomass; f = total N mineral content of soil, for up to 90 cm (rooting depth); g = total N in above-ground phanerogamic plant litter; h = total N in above-ground higher plant litter production; i = mineralization rates of N in higher plant litter; j = mineralization of cryptogamic plant litter; k = below-ground litter production; l = total N in below-ground litter standing crop; m = volatilization; n = denitrification; p = plant uptake.

Figure 3.3.4.1: N pools and sizes in Atriplex community (adapted from Gist et al. 1978).

because the plant available P reserve can become depleted in a few years' time.

In well-developed soils, a significant portion of the plant-available P is held within soil organic matter. This organic P pool does not become bound to soil minerals because the organic matter already coats and partially blocks the reactive mineral surfaces. The organic P is slowly released through decomposition of soil organic matter and thus becomes gradually available for plant uptake. These soil organic matter pools are not found in drastically disturbed soils with low organic matter content and are another example of the inherent value of existing topsoil materials.

Phosphorus deficiency is indicated on most plants by a purplish tint to the leaf and reduced plant growth. Sheaths of grasses or damaged leaves may naturally develop this color and should not be mistaken for P deficiency. Deficiency symptoms often become visible when N is limiting and root development is inadequate to explore the soil and take up P. If the soil tests indicate low to moderate P and the leaves show deficiency symptoms, mycorrhizal fungal inoculation may be required. Nitrogen fertilization may also increase root growth and improve P uptake. Excessive lime application may induce P deficiency.

The amount of plant available P in soils is estimated by measuring the amount of P dissolved into one of several extracting solutions. Because the extracts withdraw quite different amounts of P, it is critical to know which method was used before soil fertility analysis data can be interpreted. Three common methods used by commercial labs are the weak Bray (Bray # 1), the bicarbonate (Olsen) and DTPA extracts. Soils are shaken with these solutions for standard lengths of time and the amount of P in the solution is correlated with plant response in agricultural soils. In mine soils, lower target P levels are acceptable if the objective is to maintain plant cover rather than to grow and export a crop. The variable and often extreme chemical conditions of mined materials make interpretation of these agricultural based tests difficult. However, because the tests are commonly available through commercial soil testing labs, they provide an economical method of evaluating P availability on revegetation sites. A range of extractable P using two solutions is given in Table 3.3.4.2.

Field trials are useful to calibrate the results of P extraction tests to suitable P applications on the actual site. Because of the wide variety of field soil and climatic conditions, these data are not readily available in the published literature. In general terms, however, native species can be expected to grow well if extractable P is in at least the "low" range of tests used for agricultural soil. Legumes, with their higher P requirements, may require additional P fertilization. P fertilization rates commonly are 20 to 40 kg P ha^{-1}, but on weathered or very red soils, P applications in the hundreds of kg P ha^{-1} may be required. The objective should be to provide an ample supply of total soil P to support sustained plant growth, but to keep the availability of the P low enough that plants will form the beneficial mycorrhizal relationships that are typical of undisturbed soils near the revegetation site.

3.3.4.3 Potassium (K)

Plants use potassium (K) to boost enzyme activity and regulate osmosis. Although K is needed by plants in about the same amounts as N, the element is geologically more abundant and deficiencies are uncommon in western soils (Munshower 1993). Potassium levels are commonly measured in ammonium acetate (NH_4OAc) extracts, the same used to displace other nutrient cations from the soil. Available K is expressed in µg K g^1 soil and as a percentage of the soil exchange capacity. Adequate levels of K from commercial soil tests range in the low hundreds of µg K g^{-1} soil range (Table 4). K should account for between 1 and 5% of the ions on the soil CEC.

Extractable K levels measure only the ionically bound K that forms the short-term plant- available pool of this nutrient. Long-term availability depends on the mineralogy of the soil: the potentially weatherable K. Plants on soils with adequate exchangeable K but no weatherable source to replenish the exchangeable K may develop deficiencies at a later time. For example, a coarse sandy soil may be expected to become more deficient with time as K is slowly lost from the soil.

Knowledge of the mineralogy on the site can help evaluate if additional K will become available through weathering. In a study of granitic revegetation sites, for example, the exchangeable K levels were marginally low in the coarsest decomposed granite ravel and steadily increased as the granite materials became progressively more weathered (Claassen and Zasoski 1998). No supplemental K fertilizer was specified for the soil because available K is expected to increase as the soils on the site weather. A similar situation occurs with the common acid mine site mineral, jarosite (a potassium iron sulfate). Commercial soil fertility tests indicated that the jarosite material was only "moderate" in K availability, but the soil minerals had enough total K to supply hundreds of years of hypothetical grain crop production. As the pH is raised, the jarosite becomes unstable and K is gradually released. At a different mine, the acidic andesitic overburden material had been leached of K and the soil tests indicated "very low" exchangeable K. A large compost amendment containing 650 kg K ha^{-1} was used to provide a pool of plant available K for future growth requirements.

Potassium can be added as muriate of potash (KCl), as salts of nitrate (KNO_3) and phosphorus (KH_2PO_4) or in composted plant materials. Except for additional salt stress on nearly saline soils, K can be amended to soils without concerns for toxicity to plant growth.

3.3.4.4 Calcium (Ca)

Calcium is used by the plant for cell wall stability and for metabolic regulation. It is present in much higher concentrations in the plant than is actually required for growth, probably because it is usually the most common cation on the cation exchange capacity. It is measured by exchange of soil cations with ammonium acetate and is expressed as µg Ca g^{-1} soil and as a percentage of the total soil exchange capacity. Typical values range from hundreds to a few thousand µg Ca g^{-1} soil, with Ca occupying about 50% or more of the exchange capacity. In serpentinized soils, however, the Ca percent of the exchange may be much less than half of that typically found on non-serpentine soils. Samples of vegetated serpentine soils should be tested to identify sufficient Ca levels for serpentine tolerant species. In low Ca acid soils, the amount of Ca present in even the smallest lime applications (used for correction of acid reaction) will give ample Ca for plant growth. Excessive application of Ca as calcium carbonate (lime) may cause precipitation of plant available P. Ca application may also be used to counter the effects of excessive sodium. In this case, $CaSO_4$ (gypsum) would be used since it does not cause additional increases in pH.

3.3.4.5 Magnesium (Mg)

Magnesium is used by the plant for photosynthesis and for cell metabolism regulation. It is measured in the soil by exchange with ammonium acetate and is expressed either as µg Mg g^{-1} soil or

Response to fertilizer amendment	Weak Bray P	Bicarbonate P (Olsen)	Potassium (K) NH_4OAc extr.
growth response common	<5	<5	<75
probable growth response	6-14	5-10	76-125
growth response unlikely	>15	>10	>126

Table 3.3.4.2: Extractable (plant available) soil phosphorus (P) and potassium (K) levels. Likelihood of plant growth response to crop or wildlands plants indicated in the left-hand column. Compiled from Munshower 1993 and Olsen and Sommers 1983.

as a percent of the exchange. Generally, the Mg concentrations are expected to be a third or half of the Ca concentrations except in serpentine soils, where it is often found at higher concentrations than Ca. High levels of Mg are not inherently problematic as long as Ca is at least 20 to 25% of the Mg level (Bauer 1978). Acid soils with deficient Mg levels will usually get adequate Mg from magnesium carbonate included in the lime materials or from dolomitic limestone.

3.3.4.6 Sulfur (S)

Sulfur is used by the plant in protein construction. Like N, S has several biological forms and is commonly associated with soil organic matter. Excessive sulfate-S does not cause plant injury, although high S levels often indicate acid generation potential on many mined materials. Very sandy soils and very low organic matter soils may have sulfur deficiencies, indicated by yellowish color on the leaves. Gypsum applications can provide adequate plant available S without pH changes. Elemental sulfur can provide S while slowly acidifying alkaline soils, if needed.

3.3.4.7 Micronutrients

Micronutrient fertility on such complex and chemically extreme conditions as mined materials is difficult to evaluate. This difficulty occurs because only a small fraction of the total micronutrient content of the soil is available for plant growth and the analytical methods (extractants and calibration information) do not accurately represent the plant's uptake pattern of each micronutrient. In addition, the variety of mineralogical conditions on mined materials greatly changes the availability of the micronutrient to the plant root. Finally, plant tolerance to the various micronutrients varies widely among species and between ages of individuals from the same species. This combination of insensitive testing methods and a wide variety of environmental conditions makes micronutrient relationships hard to evaluate. Munshower (1994) and Williams and Schuman (1987) review the difficulties of micronutrient availability or toxicity. More detailed information is available from the book *Toxic Metals in Soil-Plant Systems* (S.M. Ross 1994, Wiley & Sons).

Generally, adjustment of soil pH to levels favorable for plant and microbial growth (pH between 5.5 and 7) will reduce the solubility of Al, Cu, Fe, Hg, Mn, Ni, and Zn to levels where they are not toxic. Molybdenum (Mo) availability, however, increases with pH.

Commercial soil analysis of micronutrients for agricultural soils (often by DTPA or AB-DTPA (ammonium bicarbonate diethylenetriamine penta-acetic acid) extracts) can be used for a general evaluation for micronutrient levels on near neutral soils. Metal availability on acid soils is highly altered by the pH with use of DTPA extractants. Inaccurate analysis may result. Micronutrients can be generally interpreted by using agricultural standards, but native plants are probably more tolerant of micronutrient toxicity or deficiency. A useful technique, especially for micronutrient questions, is to sample soil from acceptably vegetated areas and to compare it to soil from barren areas. Changes in micronutrient concentrations in the barren area may or may not represent a threat to the revegetation project, but given the complex biogeochemistry of these elements, additional information from more detailed texts or experts in micronutrient geochemistry should be sought.

3.3.4.7.0 Arsenic (As): Arsenic (As) is not usually listed as being essential for plant or animal growth, but is often found in toxic levels in mined areas. Because the thresholds of toxicity for various As compounds are not well established, comparison of reference areas and impacted areas can provide some guidance on the occurrence of toxic As levels. Because As geochemistry and availability is similar to phosphate, similar extractants can be used to assess plant-available levels of both elements. Some colorimetric methods can indicate phosphate-P when the element is actually arsenate-As. Experts should be consulted if analysis is needed in a high As soil.

3.4.7.1 Zinc (Zn): Zinc (Zn) is important for regulation of plant architecture and enzyme function and is required in very low levels within plant tissues. High Zn levels can interfere with P regulation. DTPA extractable levels of zinc in soil that are adequate for growth of plants are approximately 1 mg/kg (Munshower 1994). Mine impacted areas often have variable and occasionally much higher levels. High or toxic levels of DTPA extractable zinc are estimated to be 50-125 ppm (Munshower 1999) although one study showed that nitrogen fixation was reduced between 10 and 14 ppm DTPA extractable Zn (Yadav and Shukla 1983). Zn availability will decrease as the soil pH increases from acidic to neutrality.

3.3.4.7.2 Manganese (Mn): Manganese (Mn) is required for chloroplast structure and enzyme function. Acid soils frequently have excessive manganese levels. With partial neutralization of soil acidity to above pH 5.5, however, Mn is not expected to limit growth through toxicity except in compacted or reduced soils. High iron levels also moderate the effects of excess Mn.

3.3.4.7.3 Iron (Fe): Iron (Fe) is required for many enzyme functions. Acid soils frequently have high iron levels, but with partial neutralization, Fe solubility is so low that the ion is not toxic. High iron levels can strongly reduce P availability, but this P reduction effect is decreased as acidity is neutralized above pH 6. High levels of extractable iron, along with very high sulfate levels, indicate a potential for other acid soil-related problems.

3.3.4.7.4 Copper (Cu): Copper (Cu) is required for redox control of many enzyme systems within the cell. Toxic levels of Cu do not typically occur unless the soil is acidic. Available Cu extracted by DTPA or AB-DTPA is not well established. Because Cu bioavailability to animals is confounded by Mo availability, the two elements need to be analyzed together. DTPA extractions from Montana showed most soils contain between 0.3 and 3.0 ppm extractable Cu (Neuman et al. 1987). Copper toxicity often appears as iron deficiency (chlorosis of the leaves). Copper binds to root tips and reduces growth, often producing a stunted plant with yellowish leaves (Bennett 1993).

3.3.4.7.5 Boron (B): Boron (B) is required for cell wall structure and for regulation of membrane permeability. Boron is mobile in the soil, and therefore it can leach downward through the profile or can migrate upward from the subsurface. The difference in concentration between deficiency and toxicity is small (Barth et al. 1987). Plant available B is greatest when pH is above 5.0 (Tucker et al. 1987). Boron is present in soil as an uncharged molecule.

Because accurate extraction methods and predictive thresholds are not available, comparison of soil extracts between impacted and less disturbed reference areas is useful. Substrates that have the greatest potential to produce B toxicity are carbonaceous rocks or shales. Materials with more than 5 to 8 ppm hot water extractable B may require tolerant vegetative species (Barth et al. 1987).

3.3.4.7.6 Molybdenum (Mo): Molybdenum (Mo) reduces nitrate to ammonium inside the plant and fixes N_2 gas in symbiotic N fixation. Small grain crops are not very sensitive to Mo concentrations in soils except at extreme levels. Levels of concern for this element are poorly defined but deficiency levels limiting plant growth are rare (Munshower 1993).

The primary reason for evaluating Mo is to screen for potential damage to grazers on the revegetated site, including deer, sheep and cattle. Molybdenum toxicity (molybdenosis), results from cattle eating plant material with a high Mo content. When the Cu:Mo level in the plant tissue is 2:1 or less, the animals develop symptoms of Cu deficiency. This problem is most common on volcanic materials in the north and east parts of California.

3.4 Soil Biology

The soil physical and chemical environment provides the stage on which the biological activities of soil organisms are performed. These living organisms have vastly different requirements for moisture and nutrients and widely differing tolerances for toxic elements. Furthermore, they are often highly interdependent, so that several different life forms may provide the critical benefits of biomass production and nutrient cycling on the site. The net result of this activity is sustainable revegetation and erosion control. Another benefit of using soils with existing biological activity is that they contain years of accumulated seeds (the seed bank), many of which stay viable for a number of seasons. This seed bank may provide many desirable propagules for rehabilitation.

3.4.1 PLANT RESIDUE DECOMPOSERS

The nutrients in accumulating plant litter would rapidly tie up all the available N if it weren't for active decomposition of the litter by soil microbes and microfauna. These populations are not visible to the eye but on native soils can account for 3,000 to 5,000 kg biomass per ha or more (Alexander 1977). Soil bacteria and fungi rapidly colonize the plant residues, decomposing the soluble, easily degraded portions first. As the remaining material becomes more difficult to decompose, a succession of slower growing organisms with more complex enzyme systems colonizes the residues. Small soil arthropods accelerate the decomposition process by physically breaking up the residues into smaller pieces and by grazing on the fungi and bacterial cells, thus speeding their growth rate. Decomposition and nutrient cycling activity by decomposers may be low in revegetation soils for several reasons, including extreme pH, droughtiness, salinity, or soil compaction. When the normal cycle of residue decomposition and nutrient release is disrupted, the supply of nutrients to the plants is reduced also.

Soil microbes have a secondary effect on soil regeneration in addition to nutrient cycling. As populations grow and die, fungal and bacterial cell wall residues gradually accumulate. Decomposition of these walls is slow because they are composed of compounds that are resistant to decay, but the N contained within them gradually accumulates in the soil. In this way the soil organic matter and slowly available N pools begin to be regenerated.

Dispersion of many kinds of microbial propagules is constant and rapid through wind, animal, and equipment vectors. Other soil inhabitants, such as endomycorrhizal spores and microarthropods may disperse more slowly. An introduced inoculum could potentially be beneficial either as an interim measure, bridging the time gap between project implementation and local microbial dispersion, or as a "super-strain," that is, one which has been bred to provide a particular beneficial characteristic (such as drought, metal or salt tolerance). In order for this latter strain to persist, it must out-compete the local strains. Introduced microbes have generally been observed to be displaced by native strains in the few studies that track these effects.

3.4.2 MYCORRHIZAL FUNGI

An important group of soil fungi other than those involved in plant residue decomposition are the mycorrhizal fungi. These fungi grow in beneficial association with plant roots and form unique structures known as mycorrhizae (which means "fungus-root"). This structure is a combination of fungi growing into or around the plant root, with hyphal strands extending out into the soil. The fungi are supported by energy from plant photosynthates and they actively take up and transport P, micronutrients, and water back to the plant. This broad group of fungi is split into several sub-categories depending on the fungal groups involved and the mycorrhizal structures.

Mycorrhizal fungi that colonize many conifers and oaks are in the Basidiomycete and Ascomycete fungal groups and the fruiting bodies are commonly seen as mushrooms under the trees. The fungal symbiont grows as a dense fungal sheath around the outside of young root tips, like a cotton glove on a finger. This type is known as an ectomycorrhizae. The term "ecto" indicates that the fungi grows outside of the root cells rather than within them (Figure 3.4.2). These fungi spread rapidly by wind blown spores from the above ground fruiting body and commonly colonize drastically disturbed soils. *Pisolithus tinctorius* is a common species with many locally adapted strains. These dark brown puffball-shaped fruiting bodies can be seen scattered under pines or oaks after the fall rains begin. These fungi can live saprophytically between periods when they are symbiotically involved with a plant root.

Mycorrhizal fungi that grow on herbaceous plants and many shrubs are grouped as endomycorrhizal fungi. The term "endo" indicates that as the fungi grow they penetrate the cell walls within the cortex tissue of the root rather than growing outside of the root as a fungal sheath. Within certain cells of the root cortex, endomycorrhizae form small tree-like structures (arbuscules), which function as exchange sites for nutrients to the plant and for carbohydrates to the fungi. These fungi are sometimes known as "AM fungi" for "arbuscular mycorrhizal fungi." These fungi form small round resting structures, or spores, that are one to five times the diameter of a human hair in size and can be sieved from soil to evaluate the potential for beneficial colonization. No above-ground fruiting bodies are produced by endomycorrhizal fungi. Roots of the plant can be cleared and stained and examined under the microscope to verify that they have been colonized by the fungi. These fungi are sensitive to environmental conditions, so they can be expected to vary from site to site according to climate and soil chemistry.

Manzanitas (*Ericaceae*) are symbiotically colonized by a third (*Ericoid*) group of fungi that have combinations of EM and AM fungal structures. Members of the Amaranthaceae, Chenopodiaceae and Brassicaceae families are generally considered to be non-mycorrhizal.

Excessive phosphorus fertilization is commonly found to reduce the percentage of the plant root that is colonized by endomycorrhizal fungi. On very low nutrient sites, however, fertilization can improve overall plant growth and actually increase the total length of colonized plant roots even though the percentage of root colonized is decreased (Claassen and Zasoski 1993). Different rates of fixation of fertilizer P onto mineral surfaces and away from plant available pools can also cloud the relationship of fertilizer P and mycorrhizal colonization.

While wind dispersed ectomycorrhizal spores can travel long distances, endomycorrhizal propagules are slower to disperse. Therefore, sites that are large and barren may benefit from inoculation. Sites without previous plant growth (or with only non-mycotrophic chenopodes and mustards) that have been fumigated or that have been deeply excavated are likely to show definite plant growth response to inocula. Sites previously supporting plant growth (other than non-mycotrophic species) usually do not show clear

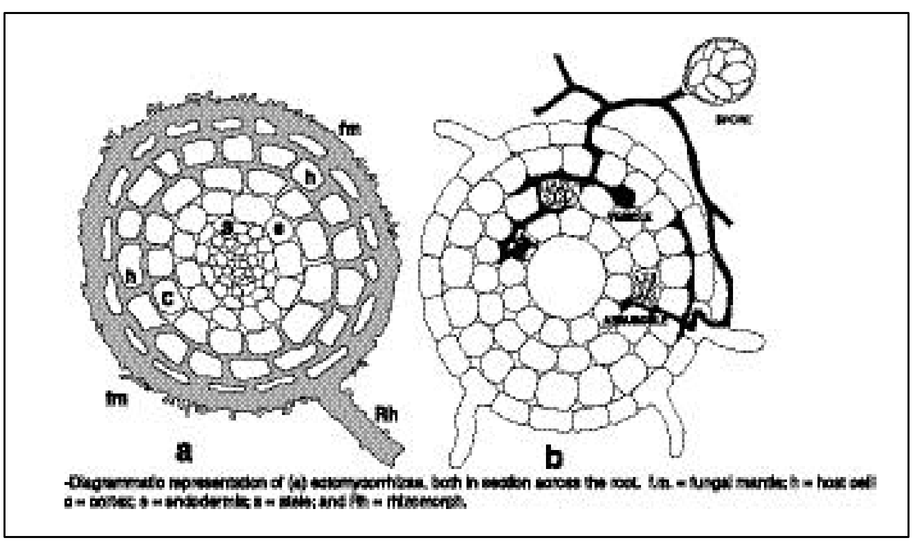


Figure 3.4.2: Structure of ecto-and endo-mycorrhizae. Reproduced from Tinker (1980) by permission of the American Society of Agronomy.

growth increases from inoculation. The effects of endomycorrhizal colonization may be as important to long-term plant community diversity patterns as it is for short-term growth effects.

The source of inocula (native source versus “universal” accessions) may also affect site performance. Fungal inocula adapted for greenhouse growth may not be adapted for growth on harsh field sites, but they may provide benefits for the first several years until native or site adapted species colonize the site. However, the introduced inocula may displace local fungi. For example, two species of mycorrhizal fungi were exchanged between field plots near Reno, NV and San Diego, CA. After three growing seasons, both fungi had persisted in their new locations. Growth was greater, however, in the original site than the transferred site, and it was greater with the host from the fungi’s location of origin. The density of the mycorrhizal fungi declined significantly at the new site and with the new host plant, even though the host plants were the same subspecies of Artemesia (Weinbaum et al. 1996). Introduced inocula placed in the surface 2 cm died out completely, but the same introduced inocula placed at 15 cm persisted in the new environment (Friese and Allen 1991).

The long term effects of new introductions are not well described. Potentially, the benefits of locally adapted inocula may be decreased by using fast growing but less effective introduced strains. Until inoculum source issues are clarified, local fungal inocula can be acquired by using small volumes (250mL; one cup) of soil from the root zones of adjacent, mycorrhizal plants. These same inoculum materials can be increased, or bulked up, under contract with a commercial inoculum producer.

Additional information on mycorrhizal fungi can be obtained from the following web addresses:
St. John, 2000:
http://www.mycorrhiza.net/ select “downloads”, then “Expert.pdf (flat)”
Brundrett et al. 2001:
http://www.ffp.csiro.au/research/mycorrhiza/
Morton, 2001:
http://invam.caf.wvu.edu/invam.htm

Although stockpiling topsoil is recommended to save and utilize this valuable resource, the process can decrease the mycorrhizal fungi activity in the soil. Stockpiled topsoil held for three years in the Great Basin had significant reduction of inoculum potential (Rives et al. 1980). Soils stockpiled for the summer construction season in Northern California, however, showed no loss in colonization potential (Claasen and Zasoski 1993).

3.4.3 N-fixation

Because N cannot be weathered out of most rock types, it must be biologically introduced into the soil. This process involves splitting atmospheric N_2 and incorporating it into organic compounds in a process known as nitrogen fixation. Generally, sunlight and photosynthesis provide the energy for the process and several kinds of microbes have the metabolic machinery to accomplish the task. The most common of these are the bacterial genera *Rhizobium* and *Bradyrhizobium* that infect (colonize) legumes such as clovers (*Trifolium*), lupines (*Lupinus*) and lotus (*Lotus*). The actinomycete *Frankia* colonizes shrubs and trees including California lilac (*Ceanothus*), antelope bitterbrush (*Purshia*) and alder (*Alnus*). Both types form nodules on the roots in which the N-fixation occurs. N-fixation rates of tens to a few hundreds of kg N ha^{-1} have been estimated for these symbioses, but the actual rates in the stressful environment of disturbed sites are probably lower. Soil crusts (bluegreen cyanobacteria and lichens) are another significant source of biologically fixed N, a product of the bluegreen algal symbiont (See flux arrow “a” in Figure 3.3.4.1).

3.5 Soil Management,Testing, and Amending Techniques

Without a topsoil, rehabilitation is extremely difficult. Thus, topsoil should be treated as an invaluable and non-replaceable resource, rather than as a commodity to be sold or a nuisance to be buried. Soils take tens to hundreds of thousands of years to form, and the process of recreating a fully functioning soil is difficult and expensive. Therefore, the best method for dealing with the soil on the project site is to protect any existing soil from disturbance. On construction or mining sites this may entail enclosing with orange construction fencing any areas that need not be disturbed.

Unfortunately, sites are often severely disturbed by the uses to which they are put, including land shaping, grading, and drainage alterations, all of which disrupt the native soils. If the topsoil cannot be preserved in place, it may be harvested, stored, and reapplied at a later date. However, the storage of the soil presents many of the problems discussed earlier, such as the potential loss of the plant available N pools and mycorrhizal fungal inocula. Alternatively, soil can be harvested from a similar, nearby site just before it is needed (taking care not to overly disturb that site as well) and brought to the project site for application. This alternative is especially pertinent to phased projects.

The most expensive alternative is to create new topsoil on the site. If this alternative is necessary, it would be wise to examine the soil in a nearby vegetated area in order to develop a model for soil regeneration. This local model will provide an example that integrates the local climate, geological material, terrain, and biological activity and that provides a realistic comparison for establishing adequate soil nutrient levels and selecting potential revegetation plant species and soil microbes.

Various projects have sought to create a soil from a mixture of fines (silt and clay), organic matter (composts, sludge, wood chips), and other additives such as gypsum or lime. These sites may grow some vegetation initially; however, studies indicate that their long-term (in excess of 30 years) viability is in question (Haigh 1992). Some projects where the topsoil was lost long ago have no option. If this is the case, a soil scientist should be consulted to determine the proper mix of materials to result in the best possible, self-sustaining growing medium.

3.5.1 MOVING SOILS WITH HEAVY MACHINERY

If soil materials are to be harvested, moved, stored or worked during the construction or mining phase, it is important that these activities occur when the soil materials are dry. Wet or damp soils are easily compacted and smeared and will be much less able to grow plants than if they were handled when dry. Bacterial and fungal spores and plant seeds are also in a resistant stage of their life cycle if the soil is dry and are more likely to survive the moving process.

Soils that are well developed, with distinctive dark, organic-rich A horizons, or clay-rich B horizons, should be moved with their relative horizons in proper order. The organic rich A horizon will have better aggregate structure to withstand raindrop impact, while the clay rich layers from greater depths may become hard and compacted if placed at the ground surface.

3.5.2 PLACEMENT OF SOIL MATERIALS WITH BENEFICIAL TEXTURE

During construction or mining activity, it may be possible to place overburden materials that are better suited for revegetation on final grade surfaces and to place materials that are difficult to revegetate where they will not be exposed following mining. For example, excessively coarse (sandy, gravelly) or fine (clayey) materials, or materials with high salt content or metal concentrations should be placed deep in the fill process, well below the root zone. Material with loamy textures should be used for the final grade of the project. Fine materials such as clays or fine silts should not be placed in lifts over coarse materials such as sands. Soil moisture in the fine materials will not be drawn down into the larger pores of the coarse layers and a perched water table will result. Plant roots will not penetrate this dryer, sandy layer, and it may become saturated and unstable.

3.5.3 STOCKPILING TOPSOIL

If possible, topsoil should be hauled directly from the harvesting site to the application site. This maintains both the biological activity and the fertility of the soil. However, if scheduling requires harvest of topsoil many months (or years) ahead of the application, construction of a topsoil stockpile may be necessary. Literature from the western US indicates that long-term stockpiling has a negative

A SPECIFICATION FOR HARVESTING AND STOCKPILING SOIL

Soil and mined materials to be left at final grade for revegetation shall be moved only in the air-dried condition. Topsoil shall be harvested to the depth of the A horizon or to 15 cm depth, whichever is greater. Where possible, topsoil materials should be hauled directly from the harvest area to the final application area. To maintain biological activity during storage in a stockpile, the depth of the pile should be less than the depth of plant root growth (about 1 m for native plants).

A SPECIFICATION FOR TOPSOIL (Haynes, personal communication)

Topsoil shall be obtained from sources within the project as shown on the plans and in conformance with the provisions in Section 19-2.07, "Selected Material," and Section 20-2.01, "Topsoil," of the Standard Specifications and these special provisions. Topsoil work shall consist of excavating, windrowing or stockpiling, removing from windrows or stockpiles, spreading, and compacting topsoil, as shown on the plans or as designated by the Engineer.

Trash and objectionable material shall be removed from sites prior to topsoil excavation. Removed trash and objectionable material shall be disposed of in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Topsoil shall be obtained by excavating the top 15 cm of material from proposed excavation and embankment areas and other areas shown on the plans or designated by the Engineer. Topsoil shall be stockpiled adjacent to the top of proposed excavation slopes and adjacent to the toe of proposed embankment slopes. When topsoil cannot be stockpiled adjacent to the slope lines as specified herein, excavated topsoil may be stockpiled at other locations when approved in writing by the Engineer. Rocks and plant material in excess of 10 cm in greatest dimension shall be removed from the excavated topsoil.

Upon completion of the grading operations for the excavation and embankment slopes and other areas to receive topsoil, the topsoil shall be spread to a uniform depth of not less than 15 cm and compacted or stabilized in a manner that retains the material in place on the slopes. The topsoil shall not be compacted or stabilized to the degree that the topsoil is not maintained as a viable growing medium.

Attention is directed to "Erosion Control" of these special provisions regarding the application of erosion control materials. Topsoil shall be placed on the designated areas before erosion control materials are applied.

A SPECIFICATION FOR SOIL NUTRIENT SAMPLING

Soils from the impacted area shall be collected from the 10-20 cm depth from each of four soil pits representing a uniform area of substrate (usually within a 3 x 3 m area) and composited to form a single sample for analysis. Four such composited samples shall be taken from each region, topographic unit, substrate type or management unit of the site, including an undisturbed vegetated reference site. Vegetated reference sites shall also have the 0 - 2 cm as well as the 30 - 50 cm subsoil depths sampled and analyzed in order to characterize target nutrient values and soil characteristics.

Soil samples shall be sieved to < 2 mm particle size and coarse fragments (>2 mm) shall be estimated as a fraction of the total soil volume and used to correct amendment rates later in the project. A total volume of 250 mL (1 cup) (or as requested by the analytical lab) of the < 2 mm material shall be collected per soil sample. Soils shall be dried by air within 2 days or by oven (< 40ºC) after collection. Soils shall be analyzed for macronutrients, micronutrients, pH, CEC, EC, SAR, and texture.

effect on the microbial activity of a soil (Rives et al. 1980). In order to maintain the biological activity, the soil should not be piled deeper than the rooting depth of the plant cover. In order to facilitate root growth, the soil should be compacted as little as possible (i.e., it should be moved or worked when dry).

If the soil is stockpiled deeper than the rooting depth of the plant cover, the energy supply for the soil is cut off. The microbial activity in the soil will steadily decline with time. Although the soil becomes biologically inactive, it still maintains the many of the textural characteristics and nutrient levels from when it was an active soil. In this respect, it is still a valuable revegetation resource; its biological activity can be regenerated more easily than a whole soil can be created from non-soil material.

3.5.4 SAMPLING FOR NUTRIENT ANALYSIS OF GROWTH MEDIA OR SOIL

Current practices and problems in sampling are reviewed by Dollhopf (2000). These sampling practices are driven by the Surface Mining Control and Reclamation Act of 1970 (SMCRA) requirement of a 0 - 120 cm depth of substrate that is suitable for plant growth. Montana, for example, requires that regraded spoils are sampled every 0.4 ha from 1-120 and 120-240 in depth. In Wyoming, samples from 76 to 304 m horizontal intervals are collected from 0 - 60 cm, and 60 - 120 cm depths. Berg (1978) recommends 5 - 25 samples per ha. Sampling schemes range from "random" (focusing on areas of interest) to systematic (with defined spacing between samples). The overriding principle for sampling soils for revegetation potential is to sample from the depth of the future rooting zone of the target plant species.

Compositing (combining multiple field samples for a single analysis) helps to average out heterogeneous mined materials, but it also runs the risk of blending or "hiding" extreme soil conditions from areas that will nonetheless cause problems in the field. Berg (1978) points out that in very heterogeneous materials such as mined materials, the range and distribution of the materials are more important than the average, and variability arising from mineralogical "hot spots" can be masked by mixing subsamples collected from multiple locations. A compromise method is to sample at the scale of individual plants (that is, mix only samples that are within 1-3 meters of each other), since fertility or toxicity conditions are also averaged through the plant's performance.

To evaluate the soil forming process or the effect of amendments on plant growth, a field evaluation approach is to sample both from 0-2 cm in depth and from 10-20 cm in depth. As revegetating soils develop, they accumulate litter and nutrients from the surface downward. A sample from 0-2 cm can indicate if nutrients are slowly reentering the soil. Sites with greater nutrient contents at the surface may be interpreted as having recent fertilizer application, which may not provide long term plant growth. An enriched surface horizon may also be interpreted as having adequate litterfall to start soil development. Surface samples from 0-2 cm may also indicate accumulations of salts that will hinder seedling germination and growth. The fertility of the rooting zone is best evaluated by sampling in the average rooting depth of approximately 10-20 cm for herbaceous plants, or deeper for shrubs.

While evaluation of the top 30 cm of soil may reflect the plant's mineral nutrient resource, soil material at deeper horizons is necessary for adequate water supply for plant growth, especially in the dry summer climate of California. Water budgets are not currently available for many Mediterranean wildlands plants, so rooting patterns of revegetated or native reference communities should be compared to the soil depths of the mine-impacted area.

To prepare the collected soil for analysis, it should be sieved to less than 2 mm, which is the chemically active particle size range (the fine earth fraction). The greater than 2 mm fraction (the coarse fraction), along with an estimate of the large stones in the field, can be used to relate the soil fertility analysis data to the actual amount of fine earth fraction on the site to a given depth. For example, if a lime requirement is estimated at 15 tons per thousand tons mined material on a fine earth fraction

A SPECIFICATION FOR COMPOSTS DERIVED FROM YARD WASTE (John Haynes, personal communication, Claassen 1999)

Compost shall be derived from green material consisting of chipped, shredded or ground vegetation or clean processed recycled wood products, or a Class A, exceptional quality biosolids compost, as required by US EPA, 40 CFR, part 503c regulations, or a combination of green material and biosolids compost. The compost shall be processed or completed to reduce weeds, seeds, pathogens and deleterious material and shall not contain paint, petroleum products, herbicides, fungicides or other chemical residues that would be harmful to plant or animal life. Other deleterious material such as plastic, glass, metal or rocks shall not exceed 0.1 percent by weight or volume. A minimum internal temperature of 135 degrees F shall be maintained for at least 15 continuous days during the composting process. The compost shall be thoroughly turned a minimum of five times during the composting process, and shall go through a minimum 90 days curing period after the 15-day thermophilic compost process has been completed. Compost shall be screened through a minimum 1/4 inch screen.

The moisture content of the compost shall not exceed 35%. Moisture content shall be determined by California Test 226. Compost products with a higher moisture content may be used provided the weight of the compost is increased to equal compost with a maximum moisture content of 35%.

Compost shall be tested for maturity/stability with a Slovita Test Kit. The compost shall measure a minimum of 6 on the Solvita maturity/stability scale for direct seeding, but may be lower if plant installation is delayed for several months.

basis, but 50% of the soil to a target depth is coarse, non-reactive stones, the lime required to actually bring the surface soil to the desired pH is only half the amount that would be needed if the whole soil were of less than 2 mm size.

Samples of the fine earth fraction are typically tested on a dry weight basis. Soil can be air dried within a few days, or oven dried at less than 40 °C. The drying process is known to alter nutrient availability to some extent, however. Mineralizable N increases after drying while extractable P decreases. These variations must be weighed against the cost and difficulty of working with fresh, refrigerated samples.

Compost incorporation should also be considered to improve infiltration. Coarse composts ripped into a low-organic matter, clayey soil provided excellent infiltration through heavy fall rains in the foothills of central California.

3.5.5 AMENDING

Amendments that are incorporated into the soil include lime, gypsum, composts, and various mulches. Lime ($CaCO_3$) is used to raise the pH of a soil. Most native soils are in the range of pH 5.5-7.5. Soils with a pH less than 6.0 are considered acid, but it is the soils with a pH less than 5.0 that may be problematic. Low pH soils are usually the result of acid generation following mining or other such activity, and are otherwise uncommon in California. The liming rate for an acid soil has to be determined based on the acid generating potential of the tailings or soil, a very site-specific determination. Gypsum ($CaSO_4$) can correct a calcium deficiency without adding additional alkalinity. Gypsum is also commonly used to displace exchangeable Na from sodic soils and replace it with Ca.

Composts come in many forms, with commercially available composted steer manure, composted sewage sludge, and municipal composts topping the list. Foodlot manure composts are saltier than dairy manure composts. Biosolids are N and P rich. The exact chemical formulation of compost (with the exception of the sewage sludge) is often not known or disclosed. Composts are a great source of organics if a soil has to be “built,” but on less disturbed sites they may provide too rich a source of N and increase weed growth over natives. Compost incorporation should be considered to improve infiltration. Course composts ripped into a low-organic matter, clayey soil provided excellent infiltration through heavy fall rains in the foothills of central California.

3.5.6 MULCHING

Mulches are applied only to the soil surface. Many different materials are used for mulching, most commonly straw, wood chips, and wood fiber mulches. Yard waste compost and pine needles are increasingly used on roadway embankments. Mulches are used in two ways:
1) as an organic additive to the soil surface to aid soil moisture retention and to control erosion, and 2) as a physical barrier to weed growth around individual trees and shrubs. Mulch application will be covered in detail under Erosion Control (Section 4). Although mulches reduce sealing from raindrop impact, they do not increase infiltration except to slow water flow off the site.

Straw mulches can be punched or crimped into the soil, greatly increasing the protection of the surface from wind and water erosion. Straw mulches are also commonly blown onto the surface of the soil and secured with a tackifying agent or netting. While this method does protect the site from erosion, the mulch-soil contact is not as good as with punching or crimping. Pine needles, which applied much like straw, form a interlocking network that resists movement by wind and traffic.

Wood fiber mulches are used in hydroseed-hydromulching applications. Hydroseeding is a process by which seed, fertilizer, and a small amount of mulch (with or without a tackifying agent) are sprayed onto the soil surface. Hydromulching is similar to hydroseeding, but lacks the seed and usually includes about two tons/acre of wood fiber mulch.

3.5.7 FERTILIZING

Fertilizer should not be added to a project without a valid reason. Past methodologies promoted by agricultural research suggested high rates of nitrogen and phosphorus-rich fertilizers be added to all sites without regard to the actual need. More recent research suggests that fertilizers should be used sparingly.

> A SPECIFICATION FOR AMENDING
>
> The substrate identified on the resoiling map will be ripped to a depth of three feet and then treated with compost and lime. This area will be treated at the rate of 9 tons of lime per acre (20 Mg/ha) and 50 cubic yards per acre (42 Mg/ha) of compost. The lime amendment shall be thoroughly mixed with the upper three feet (90 cm) of substrate of the final graded surface, which may necessitate adding it in lifts. The compost amendment shall then be applied and incorporated uniformly into the top six inches (15 cm)with a disk. The contractor's representative shall inspect during mixing to assure that the substrate has been adequately mixed. The area will then be revegetated according to the plan.

Native California plants are typically adapted to drought conditions and low levels of available nutrients in the topsoil. Adding fertilizer indiscriminately to a project utilizing native plants or seeking the return of some native habitat will greatly increase the competition with exotic weeds. Native perennial plants grow more slowly than the exotic annual grasses; therefore, only unwanted grasses and weeds may benefit from the fertilizer. Only with close attention to weed management can fertilizer be added to perennial species on a site.

Commercial fertilizers consist mainly of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S); the formulation of the fertilizer is listed on the bag is this order. Commercial fertilizers come in slow-release formulations and fast-release formulations. Fast-release fertilizers tend to encourage exotic annual grasses and should not be used on native plants. Slow-release fertilizers release the nutrients over a three-month to two-year period of time and are therefore better for use on native plants.

Composted sewage sludge is inexpensive and wastewater treatment plants are often looking for ready recipients. Many issues are associated with sewage sludge as an amendment. In previous decades, the sludges contained some heavy metals, which can inhibit growth. In experimental trials, sewage sludge was found to be high in available nitrogen, causing increased growth by exotic species compared to the more slow growing natives. But, if used carefully and sparingly (nutrient release rates should not exceed perennial plant nitrogen requirements), composted sewage sludge is still a viable product for sterile substrates, such as mine wastes. Projects using sludge should require an analysis detailing pH, percent of solids, nutrients, and heavy metals.

3.6 A Note on Serpentine Soils and Mine Wastes

Many of California's rehabilitation projects take place on unusual parent materials such as serpentine soils and mine wastes, presenting a number of challenges to the rehabilitation planner. Identifying these challenges at the onset of a project will help to minimize expensive failures.

3.6.1 SERPENTINE SOILS

The most visible sign of a serpentine soil is that, overall, the vegetation sharply contrasts with that of the surrounding non-serpentine area. Often the serpentine vegetation is more open, similar to vegetation of higher altitudes, of earlier successional stages or more dense chapparal. Serpentine soils also support a large number of rare species, endemics, or plants with disjunct distributions. While only a few serpentine species require the serpentine substrate, most of the species tolerate the serpentine soil and are poor competitors on less toxic soils.

Serpentine and ultramafic rocks (which for this purpose are lumped) are hydrothermally altered, often with high levels of heavy metals and a low calcium/magnesium ratio—a toxic combination to most plants. While many different soils arise from serpentine and ultramafic parent materials, some generalizations often hold true. These soils are high in nickel, chromium, cobalt, iron, and magnesium and low in molybdenum, nitrogen, potassium, phosphorus, and calcium. The effect of high levels of metals on plants is determined by the soil texture, pH, chemical status of the metal, and the degree to which their toxicity is modified by the presence of other elements. Calcium, in addition to being a macronutrient, is a universal ameliorant. Magnesium inhibits calcium uptake by plants and competes with calcium for exchange sites on the soil particles. A low ratio of calcium to magnesium means that less calcium will be available to the plant and less will be available to ameliorate the toxicity of the heavy metals. The high levels of metals decrease nitrogen-fixing ability of rhizobacterium, decrease the assimilation and metabolism of nitrogen in the plant, and decrease the translocation of phosphorus to the leaves.

Unless an extensive program is undertaken to change the chemistry of a serpentine site (through the addition of calcium and fertilizers), the site-indigenous species are the best choice for rehabilitation of that site. These plants are adapted to the stressful soil environment, but tend to be very slow growing; therefore, extra effort should be put into erosion control measures.

3.6.2 MINE WASTES

Some of the problems associated with trying to turn mine waste into a growth medium have been touched on in the prior sections. Mine wastes can be inhospitable to plants because of the poor quality physical "soil" characteristics. That is, they typically are often coarse in texture, which increases drought stress, and lack fines, which are necessary for ion exchange. Mine wastes typically lack any type of soil structure, which can lead to long-term compaction problems. Mine wastes may be darker in color than a native soil, which increases soil temperature on a barren substrate, or nearly white in color, which increases reflection of solar energy. A significant increase in soil temperature during summer months or an increase in reflectivity may burn young plantings. Many of the above physical shortcomings of mine waste can be treated by the addition of organic matter and surface mulches.

Chemically, mine wastes may be inhospitable because they lack CEC, organic matter, and essential nutrients, and because they have either a high (alkaline) or low (acid) pH. The wastes may also be significantly higher in metals. The interaction between pH and the availability of metals was discussed previously. All these issues will impact the ability of the growth media to provide nutrients to the plants. Adjusting the pH of the substrate with lime (if acid), or elemental sulfur (if alkaline), and amending with organic matter and fertilizers are common treatments for the above substrate ailments.

Perhaps the most difficult property to mimic is the native soil biology. Mine wastes are usually devoid of soil macro-organisms and the essential microorganisms. Various projects have tried inoculating the sterile wastes by adding a veneer of topsoil (assumed to be teeming with life) or by adding a spoonful of topsoil into planting holes. The results from simply adding topsoil to planting holes has produced mixed results on mine sites in California. Some researchers have collected site-specific mycorrhizae fungi and increased it in the lab to use as an inoculum in the field. Commercial mycorrhizal inoculum is also available and has been used in California.

No matter the techniques used to build a soil from a mine waste, it is cheaper to stockpile and respread the native topsoil, if it is available.

4.0 SLOPE PROTECTION AND EROSION CONTROL

An entire book could be written on just this one topic; as a matter of fact several excellent books exist on slope protection and erosion and sediment control: Goldman et al. 1986, Association of Bay Area Governments (ABAG) 1995, and McCullah 1994. Sample specifications, guidelines and CAD-ready drawings are available from Salix Applied Earthcare at *www.erosiondraw.com*. Therefore, the treatment of this topic will be somewhat limited in scope in this book, which concentrates on revegetation.

On undisturbed sites, vegetation prevents waterborne erosion by intercepting raindrops and dissipating their erosive energy. The aggregate structure of an undisturbed soil also allows for rapid infiltration. What little surface flow occurs is slowed by vegetation. Vegetation also stops windborne erosion by intercepting and slowing the wind at the soil surface: more than 90% of the windborne soil erosion occurs below a height of one foot, and 50% occurs within two inches above the soil surface. Erosion control measures work by mimicking these aspects of undisturbed systems: intercepting raindrops, increasing infiltration, and dissipating energy of surface-water flows and of surface winds.

Vegetation's ability to reduce the force of raindrops and physically stabilize the soil is often the justification behind many revegetation projects; that is, the vegetation is purely for erosion control. Short-term erosion control commonly includes only quick-growing, shallow-rooted annual grasses. In order for vegetation to perform this function on a long-term basis, the plant palette should contain a mixture of perennial species with different rooting strategies (shallow, deep, tap, fibrous). Perennial species tend to be slow growing and take at least one to two years to provide slope protection. During the initial years of the project, it is likely that bare slopes and soils will be exposed to raindrop impact. Therefore, most projects need to address the issue of erosion and slope protection, both in the short-term and long-term.

Erosion and sediment control measures that don't involve vegetation have a designed life expectancy. As an example, short-term (one or two years) measures include various mulches and tackifiers, and long-term measures include sediment basins and check dams. Either long-term or short-term, these measures are not designed to last in perpetuity, unless they are constantly maintained. Therefore, the monitoring and maintenance of the control structures should be addressed in all plans.

4.1 Grading Considerations

As previously stressed, the best erosion control measure is to avoid disturbing an area. Similarly, the project should avoid disturbing steep, unstable areas or creating such areas as an end goal. Since these cautions cannot always be heeded, many excellent references, including the Universal Building Code, are available on designing stable slopes that will minimize the erosion potential of the resulting site. An in-depth discussion of grading is beyond the scope of this book; however, some basic guidelines are needed to adequately address erosion control.

Soil erosion can be reduced on disturbed lands in several ways by:

- creating stable slopes,
- using existing contours (or reestablishing original basin topography),
- using existing drainages (or reestablishing original drainages),
- minimizing slope length and steepness (3:1 H:V, or gentler),
- diverting upslope drainages and surface flows away from exposed slopes, and
- creating a roughened seedbed.

The equipment and labor costs of recontouring are often one of the most expensive aspects of a rehabilitation plan. Any intact vegetation (and the soils that support it) that need not be removed to meet the goals of the project should be left undisturbed. The grading plan should specifically depict areas where vegetation is to be retained, and these areas will need to be delineated on the ground.

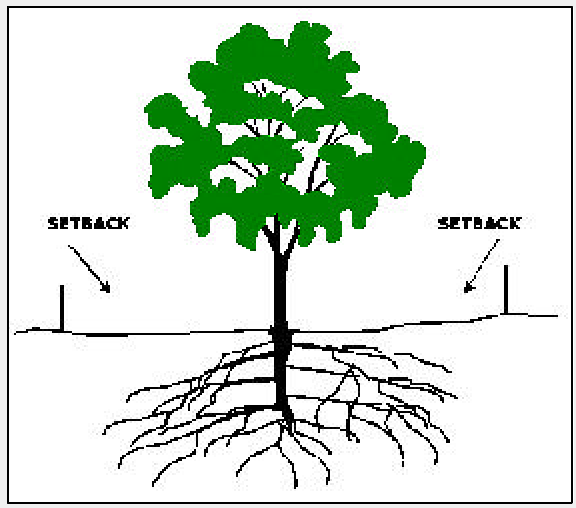
Steep slopes cause drought stress, decrease the amount of organics entering the soil (instead of decomposing in place, the organics move off the site), and cause sloughing of the topsoil. Failures on unstable slopes can sheer off the roots of the vegetation. The site's erosion potential is determined, in large part, by steepness and slope length. In general, slopes should be 3:1 (H:V) or gentler for revegetation purposes. Steeper slopes of between 2:1 (H:V) and 3:1 (H:V) can be revegetated but greater attention will need to be paid to erosion control, and planting methods may need to be slightly more intensive. Slopes steeper than 2:1 (H:V) can still be revegetated, but erosion control measures and intensive planting measures will increase costs. In addition, the expected success rates (measured as vegetative cover or density) will be lower on these steep slopes. 100 feet; often it is effective to include benches on long slopes. The rehabilitation specialist should also consider the costs and benefits of laying back the slopes to a more reasonable angle and re-establishing drainages to original contours following the construction (or mining) project. Of course, site constraints or costs may make regrading impossible.

Re-established drainages will need to be armored and the slopes revegetated to protect them from erosion and scouring. When drainages are being re-established, some type of stabilizing structure may be necessary, such as a check dam, gabbions, geotextiles, or, preferably, a biotechnical structure.

Grading practices on mine sites tend to create smooth, finished slopes, which are not conducive to plant growth and tend to exacerbate soil erosion. The final slope should present a roughened seedbed. That is, the site should have irregularities on it. For example, micro-catchments (small horizontal basins) provide a more favorable microclimate for germination and growth, and aid infiltration. Another method for adding roughness to a final slope is to "track-walk" the slope with a dozer. Care needs to be taken not to compact the substrate and the trackwalking has to be done parallel to the fall of the slope (Photo 4.1a); otherwise rills will be created (Photo 4.1b). For relatively flat areas, pitting or imprinting has proven to be beneficial in arid regions (Photo 4.1c). Rocks should be retained on the site to provide microclimates.

A SPECIFICATION FOR PROTECTION OF EXTANT VEGETATION

The contractor shall mark in the field with highly visible protective fencing or other suitable barriers those areas that are to be preserved, as outlined on the site plan. Protective fencing will be placed no closer than 10 feet out from the dripline of any trees or shrubs to be retained. Prior to the beginning of grading, the department's representative will walk the project site, check on the locations of the setbacks, and discuss any additional setback requirement.



Setback 10' from dripline of the tree.

4.2 Techniques to Control Erosion and Sediment

Erosion control is the process of keeping the soil from moving. Erosion control measures generally include actions taken to slow water down, such as

Photo 4.1a: Trackwalking correctly implemented. Trackwalking parallel to the fall of the slope creates a favorable growing environment, and also intercepts surface flows, which decreases erosion. *Photo courtesy of Land Restoration Associates.*

Photo 4.1b: Trackwalking incorrectly implemented. Trackwalking perpendicular to the fall of the slope (or on contour) does not improve the growing environment. It also favors rill formation, which increases erosion.

breaks in slopes, interceptor drains, and energy dissipaters, and actions that treat the surface of the soil so that it will intercept raindrops and increase infiltration, such as mulches and soil amendments. On the other hand, *sediment control* is the process of retaining on a site soils and fines that have already been displaced. Sediment control methods include sediment basins, check dams, and silt fences.

4.2.1 MULCHES

Common materials for mulch include straw, wood chips, wood fiber, pine needles, duff, and other crop residues. Mulches work by intercepting raindrops, increasing infiltration, and slowing surface wind and water flows. Most mulches provide only temporary cover and consist of living or dead material placed on top of the soil. The main criterion for successful mulch installation is that the mulch MUST have intimate contact with the soil.

Straw mulch can be sprayed onto a slope and then either glued down with a tackifier, tacked down beneath a net, or crimped or punched (Photo 4.2.a)

Photo 4.1c: Imprinter. Imprinting creates favorable microclimates. *Photo courtesy of Bob Dixon.*

into a site. Straw mulches are usually applied at a rate of two or three tons per acre (often in two separate applications, allowing for seeding between applications) for erosion control purposes. Higher rates, such as four tons per acre, have been used with success on sandy substrates. High applications rates of any mulch, including straw, may necessitate the addition of nitrogen (approximately 50 pounds per acre) to overcome microbial immobilization of nitrogen during decomposition of the mulch. Also, thick mulches may depress seed germination. In practice, a punched straw mulch is one of the most effective means for controlling erosion. The action of punching the straw forms a favorable microclimate for germination and leaves straw stems sticking up out of the substrate, which most closely mimics the action of live vegetation for intercepting surface wind and water flows. However, punching straw into a substrate is limited by slope angle; usually a slope can be no steeper than 3:1 (H:V). Steeper slopes have been treated by winching the punching roller up and down the slope.

Wood fiber mulches are often sprayed onto a slope either alone or as part of a hydroseed-hydromulch operation (Photo 4.2.1b). The effectiveness of a wood fiber mulch is directly related to the fiber length, the gentleness of the slope, and the strength of the tackifier used to glue it in place.

Photo 4.2.1a: Straw is punched into the substrate after spreading.

A SPECIFICATION FOR RICE STRAW MULCH

Clean rice straw, free of noxious weeds, shall be used on the site. Barley, wheat, or rye straw is not acceptable. The Contractor shall furnish evidence that clearance has been obtained from the County Agricultural Commissioner, as required by law, before straw obtained from outside the county in which it is to be used is delivered to the site.

Following the construction of the slopes and prior to the onset of the growing season, the unvegetated substrates will be exposed to erosion; therefore a straw punch will be used to temporarily stabilize this substrate. Rice straw will only be applied to upland areas, out of the floodplain of the creek.

Straw shall be uniformly spread in the areas specified in the Plans and at the rates specified herein. When weather conditions are suitable, straw may be pneumatically applied by means of equipment that will not render the straw unsuitable for incorporation into the soil. Straw shall be incorporated into the soil with a roller equipped with straight studs, made of approximately 7/8 inch steel plate, placed approximately eight inches apart and staggered. The studs shall not be less than six inches long nor more than six inches wide and shall be of such weight as to incorporate the straw sufficiently into the soil so that the straw will not support combustion.

The straw will be applied in two applications, each of 1 ton per acre. The first application will be punched or crimped into the site at 1 ton per acre. Seeding with the mix defined in the plan will follow the punching of the first straw application. After seeding, the final straw application will be punched or crimped into the site at a rate of 1 ton per acre. Containerized plants will be installed in holes augured to the appropriate depth following the final straw application.

A SPECIFICATION FOR WOOD FIBER MULCH

Unless otherwise specified, fiber shall be produced from non-recycled wood such as wood chips or similar wood materials and shall not be produced from sawdust or from paper, cardboard, or other such materials. Fiber shall be of such character that the fiber will disperse into a uniform slurry when mixed with water. Water content of the fiber before mixing into a slurry shall not exceed 15 percent of the dry weight of the fiber. Commercially packaged fiber shall have the moisture content of the fiber marked on the package. Fiber shall be colored to contrast with the area on which the fiber is to be applied and shall be nontoxic to plant or animal life. Mulch shall be wood cellulose fiber as manufactured by Weyerhaeuser Company, Comweb Corporation, or equal.

The mulch will be applied hydraulically to the site in one application of 1500 pounds per acre. The mulch will be applied evenly over the site. Special care will be taken to prevent the slurry from being sprayed onto rocks and concrete structures. (Hydromul-ching is usually preceded by hydroseeding, which is discussed in Section 5.)

Wood chip mulches, derived from on-site or off-site materials, can also be used for mulching. However, additional nitrogen may need to be added to the substrate to “feed” the microorganisms that decompose the wood chips. If on-site material is to be chipped, wood from species with allelopathic materials (toxic chemicals found in some plants), such as Eucalyptus (*Eucalyptus* spp.) and California Bay (*Umbellularia californica*), should not be used. Chips from such species may inhibit germination of other species.

Photo 4.2.1b: A hydromulch slurry can be applied to steep slopes, where access permits.

Application rates for wood fiber mulch are usually a minimum of 1500 pounds per acre for flat areas and 2000 pounds per acre on steep slopes. An advantage of hydomulching with wood fibers over spraying straw is that hydromulch can be sprayed farther onto inaccessible areas and steep slopes with a high degree of precision.

All mulches should be certified free of noxious weed and toxic substances. Unfortunately, straw mulches, even those certified, may still contain seeds of unwanted species. To be certain of minimizing the impact of these weeds on a revegetation site, straw should be selected that comes from the opposite environment of the project site. That is, rice straw (a wetland species) should be used on dryland/upland applications and dryland straws (barley, oats, wheat, etc.) should be used on wetland applications. Rice straw has the added advantage that volunteer weed densities are lower under rice straw mulch covers than under wheat straw or native grass mulch (Brown et al. 2000). Rice straw is also often preferred over wheat or barley straw because rice straw has a higher silica content than the other straws and, therefore, degrades more slowly. Barley and oat straws are more fire tolerant and may be preferable in areas prone to wildfires. Native grass hay is also becoming available, and the seed contained in it may be of value on a project. Although, mulches reduce raindrop impact erosion, they only increase infiltration by slowing water flow behind

A SPECIFICATION FOR PINE NEEDLE MULCH (Hogan 1999)

Mulch will consist of pine needles and associated duff material. Pine needles will contain no more than 15% impurities such as pine cones, twigs, or other woody organic material. Garbage shall represent no more than 0.5% of the total volume. Mulch shall contain no more than 1% by volume mineral soil and no more than 10% decomposed organic matter. The needle length of the material shall be as follows: 25% to be less than 1 inch in length; 50% to be between 1 inch and 3 inches; 25% to be greater than 3 inches. Mulch shall be tackified following application per the manufacturer's recommendations.

Pine mulch shall be applied by pneumatic application equipment (blower) in order to attain the greatest mulch-surface contact. Pine mulch shall be applied to a uniform thickness of 1.5 inches to the entire project area as delineated in the plans.

A SPECIFICATION FOR DUFF APPLICATION (John Haynes, personal communication)

This work shall consist of excavating, stockpiling, removing from stockpiles, spreading, and compacting duff in conformance with these special provisions. Duff shall consist of a mixture of existing decomposed, chopped, broken or chipped plant material, leaves, grasses, weeds, and other plant material excavated from areas within the project limits. Existing shrubs and other small plants shall be incorporated into the duff by discing, or by other methods that will break or chop the material into particles not greater than 150 mm in greatest dimension.

When duff is to be excavated to a specified depth, duff may consist of plant material and soil. Rocks and plant material in excess of 150 mm in greatest dimension shall be removed from the excavated duff. Trash and objectionable material shall be removed from duff excavation sites prior to duff excavation. The trash and objection-able material shall be removed and disposed of outside the highway right of way in conformance with the provisions in Section 7-l.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

Areas of duff excavation shall be shown on the plans.

Duff shall be obtained by excavating the top 10 cm of existing material from proposed excavation and embankment areas and other areas designated on the plans. Duff shall be stockpiled along the top of proposed excavation slopes and along the toe of proposed embankment slopes. When duff cannot be stockpiled outside the slope lines as specified herein, excavated duff material may be stockpiled at other locations when designated by the Engineer.

Areas to receive duff excavation shall be shown on the plans. Upon completion of the grading operations for the excavation and embankment slopes and other areas to receive duff, the duff shall be spread on the areas designated to receive duff. Duff shall be placed to a uniform depth of not less than 10 cm and shall be compacted or stabilized in a manner that retains the material in place on the slopes. Duff shall not be compacted or stabilized to the degree that the duff is not maintained as a viable growing medium.

Duff shall be placed on designated excavation and embankment slopes prior to applying erosion control materials. Erosion control materials shall be furnished and applied as specified in these special provisions.

A SPECIFICATION FOR SOIL STABILIZING COMPOUND

Soil stabilizing compound shall be a concentrated liquid chemical that forms a plastic film upon drying and allows water and air to penetrate. The film shall be nonflammable and shall have an effective life of at least two years. Soil stabilizing compound shall be nontoxic to plant or animal life. In the cured state, the stabilizing compound shall not be re-emulsifiable. The material shall be registered with and licensed by the State of California, Department of Food and Agriculture, as an "auxiliary soil chemical." The soil stabilizer shall be a copolymer emulsion consisting of at least 90% acrylic. The acrylic emulsion shall be disbursed in water. The soil stabilizing compound shall include the constituent sodium silicate that assists in creating a crust through the cohesive bonding of the surface soil particles to a depth sufficient to stabilize the soil surface. Further, the compound shall contain an anti-foaming agent, allowing said compound to be mixed within a hydraulic device without prohibitive foaming. When the compound is mixed with water and applied to the soil, it shall not change the pH factor of the soil more than one tenth of a pH unit. The compound shall contain a color additive which will assist the applicator in the uniform application of the product after mixing with water and which will disappear from the soil surface with 36 hours of application.

The soil stabilizing compound shall be applied to the slope at the rate and as specified in the manufacturer's specifications. The compound shall be applied following all site work, including straw punching, seeding and planting of containerized species. Entry onto the site shall be restricted after application.

each straw or fiber. Soils with infiltration limitations, therefore, should also be subjected to ripping and compost incorporation to improve soil porosity.

4.2.2 SOIL STABILIZING COMPOUNDS (TACKIFIERS)

Soil stabilizing compounds, also known as tackifers, work by chemically gluing a mulch or substrate in place. Occasionally, tackifers have been used directly on the soil surface, but most often these are used in conjunction with some type of straw or fiber mulch. Tackifers can be made from asphalt, gum, and plastics, but they should be proven to not be toxic to plant growth and to not physically impede plant growth by sealing the soil surface. Tackifers are mixed in a water solution and hydraulically applied to the soil or mulch.

4.2.3 GRAVEL MULCH

In many arid areas, coarse fragments (gravel and rocks), not plants, act as the agent preventing erosion. Gravel is most effective in protecting a site from wind erosion in arid climates where the rainfall is inadequate for a dense stand of vegetation. The gravel intercepts the wind currents near the soil surface, preventing the wind erosion of surface fines, reducing the loss of soil water through evaporation from the soil surface, and providing micro-sites beneficial to plant reestablishment. The benefits include the collection of seed and moisture and providing shade and protection for direct sunlight and desiccating winds. To mimic this natural phenomenon, a sparse layer of gravel added to the surface of a revegetation project can provide the needed erosion control and give the plants a chance to become established. The benefit of this treatment was tested alongside more conventional treatments by Caudill (1989) and found to outperform most traditional mulches.

4.2.4 COVER CROPS

On a rehabilitation project, cover crops are usually fast-growing, short-lived species (often exotic grasses) grown on a site to provide shade and cover to the desired plant species and to provide interim erosion control. The negative aspects of a cover crop are that they compete with the desired species for light and nutrients, and many annual grasses used for a cover crop have been shown to persist and outcompete the desired species (Brown et al. 1998). Sterile cover crops (e.g., Regreen, a sterile wheatgrass X wheat hybrid) may provide the benefit of a cover crop, without the negative effects. Regreen is designed to last two to three seasons, at most. Punch straw, which avoids the introduction of competing plants, can often mimic the erosion control and shade of a cover crop.

4.2.5 EROSION CONTROL BLANKETS

Geotextiles include numerous products currently on the market, such as fiber erosion control blankets, jute netting, plastic netting, silt fences, etc. These materials work by intercepting raindrops and surface flows (wind and water) and by increasing infiltration. They can be very effective when installed correctly, but they also tend to be very expensive. Incorrect installation can render the products useless or even detrimental. The installation method for blankets and netting is very similar.

For steep slopes or waterways, erosion control blankets may be indispensable. Erosion control blankets have several benefits. They can

- increase soil moisture retention,
- reduce rainfall impact on soils,
- reduce the velocity of overland and in-channel surface water runoff,
- reduce the velocity of surface wind currents,
- reduce soil loss, and
- maintain soil stability until vegetation is established.

Erosion control blankets must make intimate contact with the soil surface, with adequate stapling and appropriate overlap and trenching. It is very easy to install these materials incorrectly; therefore, manufacturer's specifications need to be followed closely. Typical installation mistakes include lack of adequate blanket-to-soil contact, too few staples, staples too short, incorrect or inadequate overlap between blankets, and inadequate "keying" (trenching and armoring) of top and toe of blanket into the substrate. Some of the blankets available are so thick that they reduce the amount of light reaching the soil surface, thereby inhibiting germination of the seeds underneath the material. It is important to choose the correct blanket for the specific job and follow installation instructions closely.

4.2.6 SEDIMENT RETENTION STRUCTURES

Effort should first be put into stopping erosion. However, since erosion can rarely be completely controlled, the next step is to keep the eroded materials from escaping the site and entering waterways. Sediment controls involve some type of structure to trap the sediment, and periodically this sediment must be cleared from the structure to maintain its designed capacity. The structures can be a simple straw bale check dam or a more complex sedimentation basin. Under the Surface Mine and Reclamation Act of 1975 (SMARA), the California Code of Regulations (CCR) requires that sedimentation basins be designed to control, at a minimum, the 20-year, 1-hour storm. The designed capacity of a basin on non-mining projects is often regulated by the permitting agency. Methods for designing standard structures are found in Goldman et al. (1986), ABAG (1995), and McCullah (1994).

Biotechnical sediment controls have been used in Europe for many decades, but have only recently become common in the US. The structures are made from plant material (in part or wholly live). The structures physically hold a slope or soil in place and take root and grow, increasing their effect on the slope through time (rather than deteriorating, as do standard engineered structures). An excellent reference for biotechnical slope protection measures is Schiechtl (1980), and for in-stream biotechnical structures, Flosi et al. (1994). A description of a few of the more common sediment retention structures follows; for information on other types of structures, please refer to the aforementioned references.

A SPECIFICATION FOR GRAVEL MULCH

On slopes gentler than 3:1 (H:V), angular gravel, ranging in size from 0.5 to 6.0 inches, will be spread on the exposed fines at a rate that will provide not less than 20 percent coverage and not more than 50 percent coverage. On slopes between 3:1 to 2:1, angular gravel, ranging in size from 2.0 to 6.0 inches will be spread on the exposed fines at a rate that will provide not less than 50 percent coverage and not more than 80 percent coverage. The gravel mulch will not be spread until all seeding and planting has been completed.

A SPECIFICATION FOR EROSION CONTROL BLANKETS

The soils of the site are subject to erosion when water is concentrated in a channel; therefore, the reconstructed creekbanks will need protection until the revegetation treatments can fully protect the site. All reconstructed creekbanks as identified on the stream realignment plan shall be protected with blankets installed according to the manufacturer's specifications.

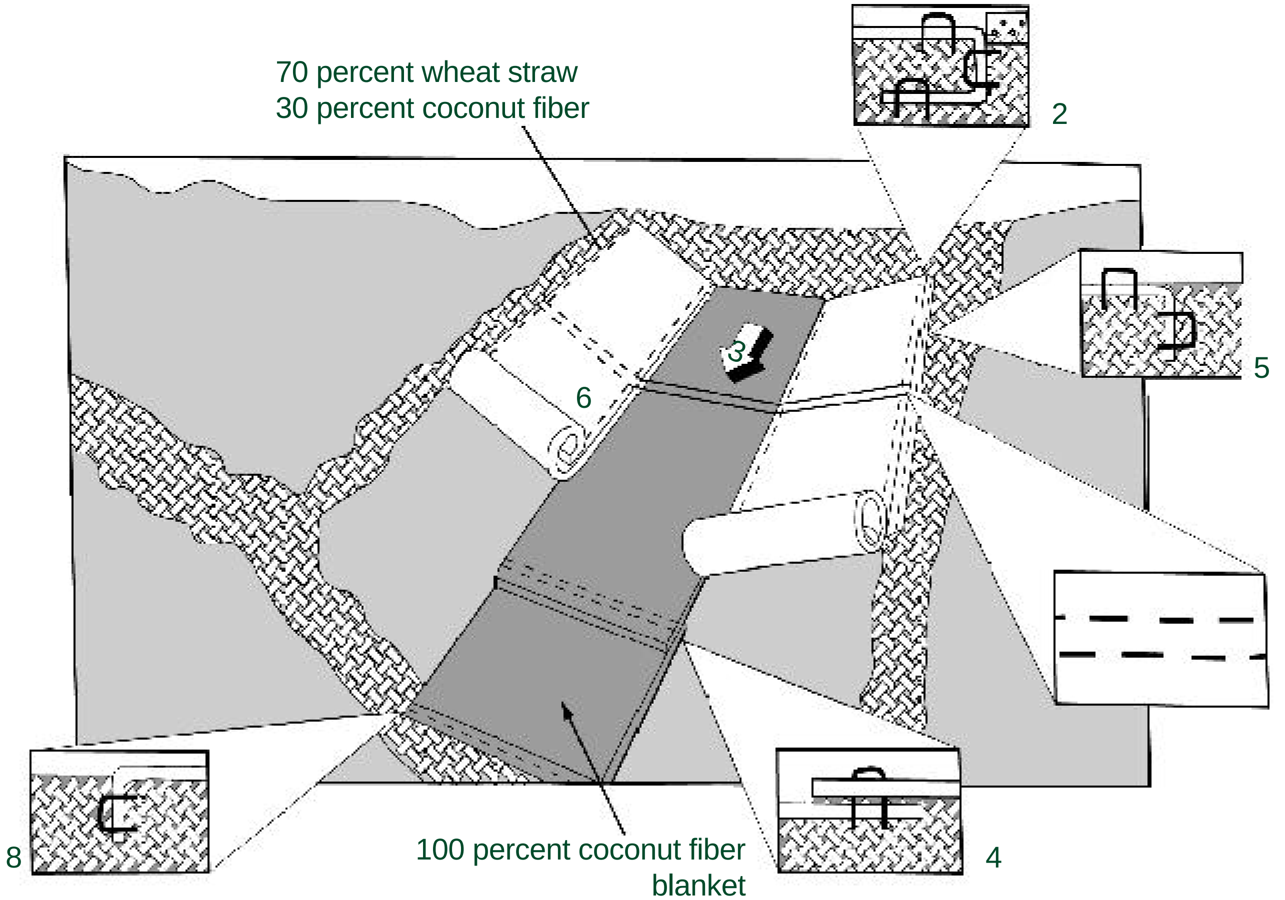
An erosion control blanket specified for in channel and heavy runoff conditions will be used on the creek bottom. The blanket shall be designed for high velocity runoff and be made of long-lasting 100 percent coconut fiber, with non-photodegradable netting, such as American Green C125 or similar. On the reconstructed creekbanks, a less durable blanket will be used. The blanket should contain no seeds and should be composed of UV stabilized netting. The blanket should be composed of 70 percent wheat straw and 30 percent coconut fiber, with long lasting UV stabilized black netting on one side and lightweight netting on the other side, such as North American Green SC150 or equal.

Blankets shall be installed according to the manufacturer's specifications, following mulching, seeding, and fertilizing, but before the installation of cuttings. Blankets shall have good contact with the soil surface throughout their length. For slope treatments, installation shall begin at the top of the slope. Installation for channel treatments shall begin at the top of the channel. The beginning edge of the blanket shall be buried in a 6 inch deep trench, backfilled with compacted soil or gravel, with an additional armoring of rocks for the channel treatment. Blankets shall be overlapped and stapled according to the manufacturer's specifications for the type of blanket and treatment area.

A SPECIFICATION FOR PLASTIC NETTING

The netting should be approximately 3/4 x 3/4 inch in rolls 15 feet wide or more. The plastic netting to be used on the site must have a minimum lifetime of 2 years under the high radiation conditions of the site. The netting shall be secured with 12-inch staples, according to the manufacturer's specifications.

EROSION CONTROL BLANKET INSTALLATION



1. Prepare soil before installing blankets, including application of lime, fertilizer and seed (step not shown).
2. Begin at the top of the channel by anchoring the blanket in a 6” deep x 6” wide trench. Backfill and compact the trench after sampling.
3. Roll center blanket in direction of water flow on bottom of channel.
4. Place blankets end over end (shingle style) with a 6” overlap. Use a double row of staggered staples 4” apart to secure blankets.
5. Full length edge of blankets must be anchored in 6” deep x 6” wide trench. Backfill and compact the trench after stapling.
6. Blankets on side slopes must be overlapped 4” over the center blanket and stapled.
7. A staple check slot is required at 30 foot intervals. Use a row of staples 4” apart over the entire width of the channel. Place a second row 4” below the first row in a staggered pattern.
8. The terminal end of the blankets must be anchored in a 6” wide trench. Backfill and compact trench after stapling.

Secure the blankets with an additional 3-5 staples per square yard in a regular pattern.

Note: Horizontal staple spacing should be altered if necessary to allow staples to secure the critical points along the channel surface.

Reference: Modified from North American Green

A SPECIFICATION FOR
STRAW BALE CHECK DAMS

Temporary straw bales will be used for drainage control. Prior to recontouring and respreading topsoil, straw bales will be installed at the toe of the slope parallel to the creek in the locations identified on the resoiling plan. Sediment retention facilities will be maintained so that fines or rocks do not enter the creeks. Periodic removal of trapped material shall be done so that the integrity and strength of the bales are not diminished. Straw bales shall be installed using standard methods as depicted in the following figure.

The bales will be clean rice straw bales, free of noxious weeds. Bales will be placed in a shallow trench excavated four inches deep for the width of the bale. Bales should be installed on contour, with ends tightly abutted. Baling wire should be oriented across the sides of the bale rather than around it. They will be secured with a piece of rebar driven through the bales and into the soil a minimum of 1.5 feet deep, on a minimum of 2 feet intervals. Gaps between straw bales should be filled with loose straw. The trench should be backfilled with soil and compacted. The downslope side of the trench should be level with adjacent ground surface while that of the uphill side filled approximately four inches above grade.

4.2.6.1 Straw Bale Check Dams

Straw bale check dams work by intercepting surface flows and trapping the sediment. They are often used in place of silt fences, largely because the materials are readily available and less expensive. Straw bale check dams (straw dikes), like silt fences, should only be used for low flow conditions. The life expectancy of straw bale check dams depends on the amount of moisture they intercept. Bales commonly last about three months under wet conditions and should be replaced if they start to disintegrate. They can be removed from the slope once the area above the bales has stabilized.

4.2.6.2 Silt Fences

Silt fences work by intercepting and detaining sediment on the site. Silt fences are made from geotextiles that have low permeability, thereby slowing the water long enough for the fines to drop out of the surface flows.They generally have a lower permeability than do straw bales, and so trap more sediment; in addition, they last through multiple seasons. As with straw bale check dams, silt fences should be used for low flow conditions. As with all sediment traps, silt fences need to be maintained; lack of maintenance can exacerbate erosion on a site (Photo 4.2.6.2). Deposits behind the fences need to be removed when filled to 1/2 of the height of the fence or when the fence bulges from the weight of the sediments.

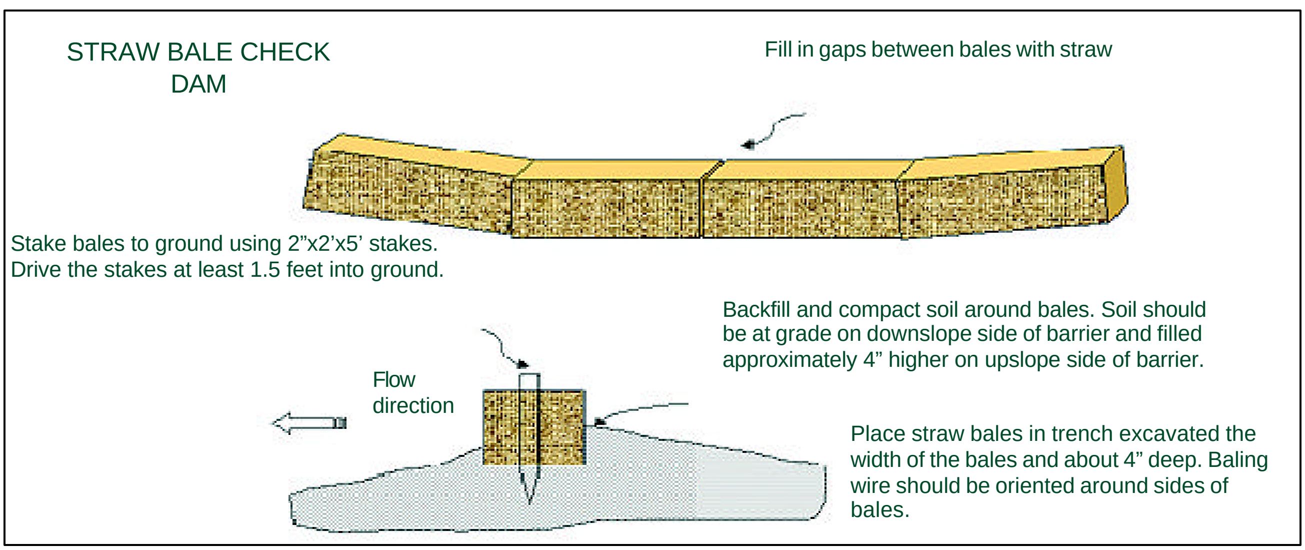


Photo 4.2.6.2: Silt fences causing erosion. Silt fences have to be maintained in order to remain effective.

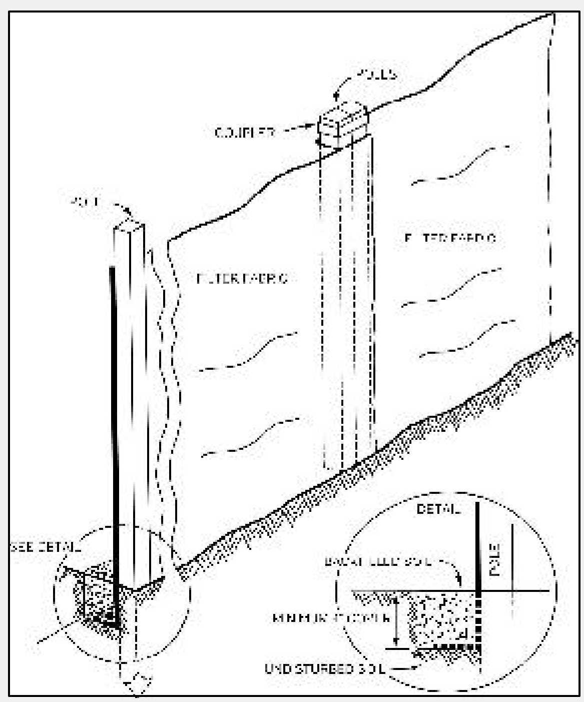
4.2.6.3 Straw Wattles

Straw wattles are based on the same principle as straw bale check dams and silt fences; that is, they intercept and detain sediment. A straw wattle is a tube of netting stuffed with straw, usually rice straw. Straw wattles are less expensive that silt fences, integrate into the landscape better than silt fences, and are more flexible than silt fences. (Photo 4.2.6.3) Unlike silt fences, straw wattles are built not to last more than 2 years. They are an interim control measure, and, as such, do not require the removal of deposits. As with silt fences they are trenched-in on contour.

A SPECIFICATION FOR SILT FENCES

Silt fences shall be made of 3 feet x 100 feet woven polypropylene yarns with pockets 6 feet on center such as those manufactured by Amoco. The silt fences shall meet or exceed the following specifications:
Grab Tensile - 100 lbs;
Grab Elongation - 15 percent;
Mullen Burst - 275 psi;
Trapezoidal Tear - 50 lbs;
U V Resistance - 80 percent;
AOS, US Sieve Number 30/40;
Permittivity - 90 gal/min/ft2.

Silt fences shall be installed per the manufacturer's specifications, including trenching in the bottom of the fence 8 inches deep and backfilling the trench with compacted soil or gravel; an example is included in the following figure. Periodic removal of trapped material shall be done so that the integrity and strength of the fencing is not diminished.



A SPECIFICATION FOR STRAW WATTLES

Straw wattles shall be manufactured from rice straw and be wrapped in a tubular black plastic netting such as those manufactured by California Straw Works. The netting shall have a strand thickness of 0.30 inch, a knot thickness of 0.055, and a weight of 0.35 ounce per foot (each plus or minus 10 percent); they shall be made from 85 percent high density polyethylene, 14 percent ethyl vinyl acetate and 1 percent color for UV inhibition. Straw wattle shall be nine inches in diameter (plus or minus one inch), twenty-five feet long (plus or minus 0.5 feet) and weigh approximately 30 pounds (plus or minus 10 percent).

The soils and revegetated areas of the steep-sided pit area are prone to erosion when precipitation rates are high (during November to March). Straw wattles will be installed along contour on steep slopes after the seeding and straw punch application, but prior to the containerized plant installation. The straw wattles shall be placed on contours and staked with 3/4 X 1/2 X 24 inch wood stakes at four foot on center. The ends of the adjacent straw wattles shall be abutted to each other snugly.

Photo 4.2.6.3: Straw wattles. Straw wattle installation on contour at Gambonini Mercury Mine.

4.2.6.4 Willow Wattles

Willow wattles are the most common type of biotechnical erosion control measures used in the western United States. They work best when live material is used, but dead material can be incorporated as well. For best results, live but dormant willow branches are cut and placed into compact, linear bundles called wattles. These wattles are interlaced, end to end, in trenches along the contour of the slope (Figure 4.2.6.4). The trenches are backfilled with soil up to about 1/2 of the width of the wattles. These wattles slow surface flows, causing sediment to drop out, and can perform this function whether dead or alive. However, if live material is used and survives (which requires adequate summer moisture), then the wattle structure takes root and grows stronger (and more dense) with time, never needing to have the deposits removed as with silt fences. Willows are very adept at transpiring large quantities of water, and therefore, also help to dry out small seeps in newly formed slopes.

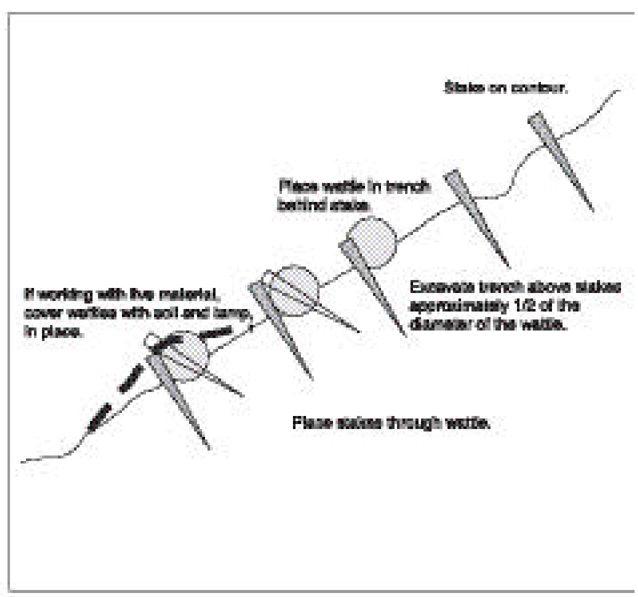
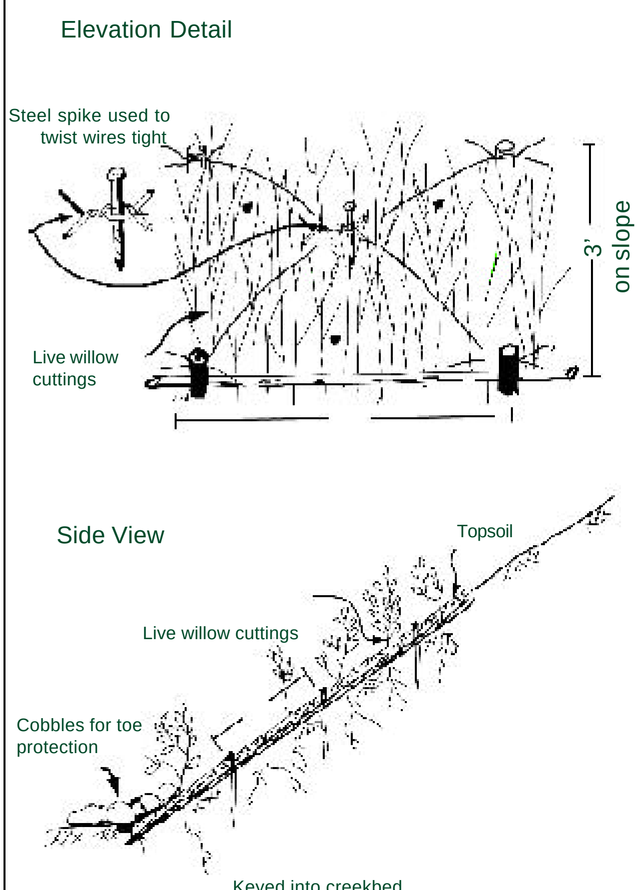


Figure 4.2.6.4: Placement and staking of willow wattles on contour.

4.2.6.5 Brushmattresses

Brushmattresses are usually installed on creek banks to prevent erosion when the creek floods. Brushmattress material may be made from living or dead plant material or a combination of both; however, the best results are achieved using as much live material as possible. If live material is used, brushmattresses are installed while the plants are dormant. In either case, straight branches at least 60 inches long work best. These are placed side by side on a slope, parallel to the fall line, and secured in place. In this position, they slow water flow and trap sediment. As with willow wattles, the brushmattress may take root and become stronger over time.

BRUSHMATTRESS DETAIL



A SPECIFICATION FOR BRUSHMATTRESSES

Material from the clearing of the new creekbed should be available for construct-ion of this structure. Brushmattresses will be constructed with branches placed closely together on the ground to achieve compl-ete cover. The butt ends of the branches will be placed in the soil upslope. If the length of the branches is not adequate to cover the entire slope, the branches of the lower row(s) must overlap the branches of the upper row(s) by at least one foot. The brushmattress will be tied to the ground with cross-laid branches and wire in rows approximately 36 inches apart, as depicted in the following figure. Live or dead wooden pegs are driven into the ground 24 to 36 inches apart and eight to 10 inches deep. The wires are tied to the pegs and the pegs are then driven into the ground. The increasing tension on the brush-mattress ensures that the branches will lie firmly on the ground.

The entire brushmattress will then be covered lightly with one to two inches of topsoil. Once the brushmattress is installed, live willow cuttings will be planted through the brushmattress on three-foot centers.

5.0 PLANT MATERIALS: SELECTION, SOURCES, AND PLANTING

One of the most commonly asked questions in restoration is what plants should be selected for the site and how should they be planted. The following information should help practitioners make the decisions that will answer this question for a particular project site; however, it is not a cookbook of seed mixes. Familiarity with the plants and ecosystem of the site and with general principles of ecology is crucial to making good choices.

5.1 Selection of Species

The selection of species to be used on the site will largely depend upon the goals of the project and the site's rehabilitation potential. There may be special interest species (rare, endangered, threatened, or game species) included in the site goals. Selection of plant species begins with determining the target vegetation type, its successional status, and the expected disturbance regime of the site (e.g., trampling, grazing, burning).

For non-successional or early successional vegetation types (which are most common in California), the best method for determining the species to plant begins with a quantitative assessment of intact habitat of the target vegetation type. A representative site should be found that has a setting similar to the project site (aspect, elevation, soils, and hydrology), and the species composition and abundance should be determined through sampling. For mining projects, the pre-project vegetation may provide the best comparison. The greater the number of species reintroduced to the site, the greater the chance for success. As a guideline, a minimum of 30 percent of the species should be reintroduced. The native species to be reintroduced should fall into at least one of the following groups:

1) dominant to abundant species (present in 30 percent or more of sample plots),
2) naturally invasive species (as observed in disturbed locations),
3) species known to provide ample quantities of viable seed,
4) species known to be easy to propagate,
5) uncommon species that rarely reinvade or have slow growth rates and provide valuable structure to the site (e.g., Joshua trees (*Yucca brevifolia*)),
6) species known to provide habitat for a target species,
7) aesthetically pleasing species (e.g., California poppy (*Eschscholzia californica*)), or
8) special interest species, if part of the project goals.

In addition, species in the mixture should have different rooting strategies. In general, annual species have shallow rooting systems and perennial species have deeper roots (Figure 5.1). Roots of the chosen species will compete with each other less if they occupy different zones in the soil. Deep-rooting species should be part of any long-term revegetation strategy because they provide good erosion control and can contribute to surficial slope stability.

5.1.1 DETERMINING THE PLANT PALETTE

"Plant palette" is a landscaping term for the list of species that will be included in a revegetation plan. This palette can be developed from the list of species that formerly occupied the site or that grow in a reference site. For example, the following is a list of species (Table 5.1.1a) found on a small desert site in the upper Mojave that receives approximately six inches of rain per year (DOC 1994). Using the groups of desirable plant traits listed in Section 5.1, a subset of the plants in this table formed the plant palette for restoration on that site.

Because this is a desert site, emphasis was placed on using perennial species, because annuals provide little cover and erosion control for the majority of the year. The most abundant species were creosote bush and shadscale. Out of the abundant to dominant shrub species, the following are known to be naturally invasive: cheese-bush, burrobush, desert asylum, desert holly, and desert mallow. Plants that produce abundant seed and are relatively easy to propagate are cheese-bush, burrobush, desert holly, and desert mallow. All three cactus species listed can be transplanted, and since cacti are widely spaced on this site and will likely not reinvade very quickly, representative specimens could be transplanted to the site. One of the few annual species that can aid in desert revegetation is woolly plantain because it is usually abundant, it is naturally invasive, it provides cover, it produces adequate seed, and it is relatively easy to grow. Based on all these considerations, our species list for reintroduction was creosote bush, shadscale, cheese-bush, burrobush, desert asylum, desert holly, desert mallow, the three cactus species, and woolly plantain, all indicated with an asterisk in the table. The cacti were transplanted, shadscale and leather-leaved viguiera were grown in containers and then planted on the site, and the remaining species were planted as seed. Red brome, an invasive exotic, was not included in the plant palette. Reintroducing such an invasive species would subvert the goal of restoring a native habitat.

By diversifying the species selection and the propagule type, the chances of success are greater, the diversity of the resulting site is greater, and the root systems of the selected species are less likely to compete.

Appendix A provides suggestions and information on species that are commonly used for rehabilitation for each of the geographic subregions of California. These subregions are defined in Figure 5.1.1 and generally follow those of the *Jepson Manual* (Hickman 1993). These tables are intended to help the practitioner make decisions; they should not be considered all-inclusive or used as a recipe for devising plant palettes.

Figure 5.1: Rooting stratagies. Choose a diverse mixture of species whose roots will occupy different areas of the soil.

Table 5.1.1a: Caltrans Material Site Species List (DOC 1994)

Scientific Name	Common Name	Notes
*Larrea tridentata**	creosote bush	very dominant shrub
*Atriplex confertifolia**	shadscale	very dominant shrub
*Hymenoclea salsola**	cheese-bush	dominant shrub
*Ambrosia dumosa**	burrobush	dominant shrub
Bebbia juncea var. *aspera*	sweetbush	dominant shrub
Viguiera reticulata	leather-leaved viguiera	dominant shrub
*Lepidium fremontii**	desert asylum	dominant subshrub
*Atriplex hymenolytra**	desert holly	dominant shrub
*Sphaeralcea ambiguua**	desert mallow	dominant subshrub
Opuntia basilaris var. *basilaris**	beavertail cactus	uncommon cactus
*Echinocactus polycephalus**	cottontop cactus	uncommon cactus
*Opuntia bigelovii**	teddy-bear cholla	uncommon cactus
Chaenactis stevioides	Esteve's pincushion	common herb
Mirabilis bigelovii var. *retrorsa*	four-o'clock	common herb
Eriogonum inflatum	desert trumpet	common herb
Chorizanthe rigida	rigid spineflower	common herb
Bromus madritensis ssp. *rubens*^	red brome	common grass
*Plantago ovata**	woolly plantain	common herb
Erioneuron pulchellum	fluff grass	common herb
Phacelia crenulata	phacelia	common herb
Mimulus bigelovii	Bigelow mimulus	common herb
Linanthus demissus	linanthus	common herb
Camissonia cardiophylla ssp. *robusta*	evening primrose	common herb
Monoptilon bellioides	desert star	common herb
Cryptantha pterocarpa, C. angustifolia, C.echinella	forget-me-nots	common herbs

* Indicates included in plant palette; ^ indicates an invasive exotic that should not be used.

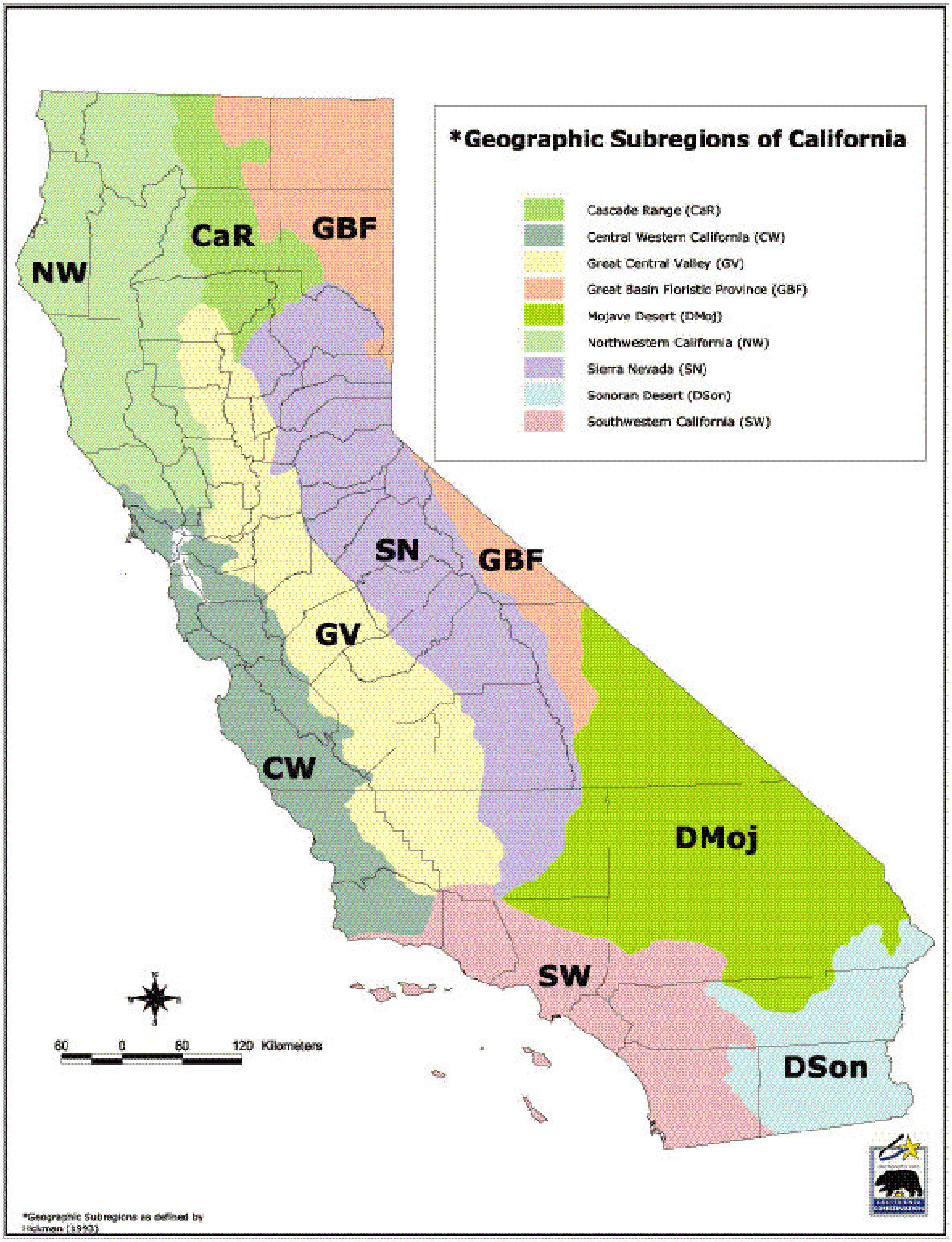


Figure 5.1.1 Geographic subregions of California

COLLECTING GUIDELINES

The following collection guidelines are condensed and modified from Guinon (1992) and can be used for most species; however, these guidelines are not appropriate for narrowly endemic species or rare and endangered species.

1) Collect from sites closely related ECOLOGICALLY to the rehabilitation site. Collection need not be restricted to project boundaries, but should be restricted by ecological boundaries (watershed, elevation, aspect, rainfall, soil type, etc.). Some indication of the genetic boundary of a species can be gained from the pollination strategy of the plant. The genes of a wind-pollinated species will be more broadly distributed than those of insect-pollinated species.

2) Limit inbreeding potential. Collect propagules from a large number (50-100) of widely spaced (100 meters) individuals, rather than from a few close relatives, to limit inbreeding on the rehabilitation site and to diversify the gene pool. Once again, the pollination strategy (e.g., wind or insect) will help determine the needed spacing of the donor plants.

3) Avoid genetically contaminated sources. Donor plants growing in proximity with closely related exotic species (where genetic contamination may have occurred) should be avoided.

4) Document the source. The geographic origin of the material should be documented and the material labeled until installed on the rehabilitation site.

5.2 Plant Material Source

Many plant species comprise local ecotypes that are narrowly adapted to local climate and edaphic conditions (Plummer et al. 1955, 1968). The plants with the best chance of survival on a site are, therefore, those ecotypes that are growing on (or near) the site (Millar and Libby 1989). Nonlocal plants, even of the same species, may not prosper on the site. They may also contaminate the local gene pool. The results of interbreeding between nonlocal and wild local native stock can be adverse and permanent.

If native plants are used, the best policy is to collect plant materials from on or near the site. Therefore, plant materials for each of the designated species should be obtained from the same region as the project site. Some general guidelines are that the seed should be collected within the same watershed as the project site, within 500 vertical feet of the elevation of the site, on the same aspect and soil type, etc.

In addition, a genetically diverse collection of the local ecotype will increase the likelihood of success of the rehabilitation project. With this principle in mind, the forest nursery profession has developed seed zones for the collection of seed of commercial tree species (Figure 5.2). The development of these seed zones required decades of research on a very limited number of species. Unfortunately, this type of data doesn't exist for the remaining thousands of California native plants. Until such data become available, the guidelines developed by Guinon (1992) are commonly used on revegetation sites in California.

A good reference for suppliers of seed and people who will custom collect seed for a project is *Nursery Sources for California Native Plants* (DOC 1995). This publication lists over 1400 taxa and the nurseries that supply each taxon. If native plant seed is obtained from a supplier, the seed should have been collected from, or grown out from, a seed source as close to the project site as possible.

Figure 5.2: California tree seed zone map.

A SPECIFICATION FOR PLANT PROCUREMENT

Plant materials for the specified species shall be obtained from similar soils and from the same region as the mine site. For purposes of this revegetation effort, the collection region will be defined as Foothill Pine-Oak Woodland natural community and non-native annual grassland that occurs south of State Route 20, north of Camp Far West Reservoir, and within the Bear Creek Watershed, on soils with a pH less than 6.0, and at an elevation between 200 and 700 feet. Seeds obtained from commercial suppliers will arrive at the site in manufacturers' wrapping with seed tag intact. Seed tag to be removed by the County Representative. All plant substitutions require a written approval from the County Representative.

5.3 Selection of PropaguleType

Whether a species is reintroduced to the site as a seed, cutting, or containerized plant depends on climate, species and goals. Seeding is usually easier and cheaper than using cuttings or greenhouse-grown plants, and, therefore, is desirable when feasible. However, it is important to keep in mind that the germination phase of a plant is its most vulnerable phase. If the site is unusually stressful, i.e., too dry, too wet, too acidic, too alkaline, etc., then more emphasis should be placed on using cuttings and containerized plants, thereby bypassing the germination phase. In general, seeding should not be used in the low deserts, because the probability of success is very low in areas with annual rainfalls of less than six inches per year. Juhren et al. (1956) showed that in the Joshua Tree National Monument desert of California, 0.2-0.6 inches (5.2-15mm) is the minimum amount of rain during the autumn required for the germination of winter annuals. The argument can be made that seed sown in low deserts (without adequate rainfall) will remain dormant until a favorable year, and therefore, should still be considered. Seed predation and wind erosion are the arguments against this "seeds will wait until the water comes" scenario. Some suggestions for propagule type are included in Appendix A: Species commonly used in rehabilitation.

Some species are known to be difficult to grow from seed and are best grown in a greenhouse in containers from cuttings or from seeds and then transplanted to the site. For example, among the desert species in Table 5.1.1a, both shadscale and leather-leaved viguiera are difficult to grow from seed and are best introduced to the site after having been grown in containers. Willows grow readily from cuttings, making seeding not worth the effort. Many aquatic species, e.g., cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), and pickleweed (*Salicornia* spp.), grow readily from stem or root cuttings. Some species, e.g., saltgrass (*Distichilis spicata*) and dunegrass (*Leymus mollis*), produce little viable seed and are best grown from cuttings or plugs. Obviously, some familiarity with the life cycle and ecology of the desired species will help in making these decisions. The availability of seeds or plant materials will also determine the choice of propagule.

At times, project goals may determine the propagule type and container size. For example, if the project requires replacement of Least Bell's Vireo nesting habitat within five years, then large containerized trees (5 to 10 gallons) may be necessary.

5.3.1 SEED COLLECTION AND TREATMENT

The project planning and scheduling needs to include time for collection or procurement of the seeds. Seeds may need to be collected from the wild for the native seed mix, requiring at least one year lead-time. For deserts, adequate seed set may happen only after favorable years (rainy), which happens, on average, once every ten years. If plants are to be grown out in the nursery from the seed, then seed collection will need to precede the scheduled planting date by at least one year, with some species (e.g., *Arctostaphylos* spp.) needing at least two years. A good article on the issues associated with seed collection is *Native Seed Collection, Processing and Storage for Revegetation Projects in the Western U.S.* (Lippett et al. 1994). Another excellent reference for seed treatment is *Seed Propagation of Native California Plants* (Emery 1988).

5.3.1.1 Seed Collection

The timing of seed collection is critical. Seed has to be collected when it is ripe and before it falls from the plant, rots, or is eaten. Seeds of native plants don't usually all ripen at once. Therefore, the collector has to visit the plants, take samples, decide when the greatest quantity of seed is mature, and then collect. This process usually takes more than one visit to the collection site. In addition, the seed quality may vary between stands and between years. Weather can also affect seed availability; such as, seed collection following wind or rainstorms should be avoided, because storms tend to disperse the seeds. Given all these possibilities, it is often reasonable and necessary to plan to collect seeds over more than one year.

If a small quantity of seed is needed, as with most projects, seed can be collected by hand. Large quantities of seed can be collected using a vacuum harvester, a mower with a catch bag, or other harvesting equipment. A large project will demand a large quantity of seed, necessitating collection on government lands, which will require a seed collection permit.

5.3.1.2 Drying and Cleaning

Once harvested, the seed should be immediately dried, cleaned and stored appropriately. Seed can be dried in an oven with just a pilot light on, in the sun, or in a dehydrator or drier. Drying the seed is necessary to reduce the chances of fungal infestation and to facilitate cleaning. Ideally, seed should be dried to approximately 7 percent moisture.

Seeds should also be cleaned in order to accurately measure the amount of seed to be placed on the site, to diminish the possibility of contamination with weed species, and to minimize the chances of fungal or insect infestation. Cleaning entails removing the seed from the stems and chaff. Depending on the species, the desirable end product can be pure seed or seed still encased in the calyx or protective shell. Cleaning tools may include fine sandpaper, to separate the seed from the chaff and calyx, and a slanted board to separate by gravity the heavier material (seed, sand, and rocks) from the lighter chaff. Often, seed can be separated from the heavier and larger material using appropriately sized screens. If a large quantity of seed is being cleaned, a seed cleaner with a series of screens and a blower may be worth the investment. A quick internet search will result in many different models (try *www.huntsmaninc.com, www.oilseed.com,* or *www.mueller-trade.com*).

5.3.1.3 Seed Storage

Once the seed is dried and cleaned, it may need to be stored until required for planting. Seeds deteriorate through time, but with proper storage this effect can be minimized. The two most important factors affecting longevity of stored seed are seed moisture content and seed temperature. Seeds will last longest if stored at low humidity just above freezing (40°F). Seeds should be dried as quickly as possible to below 14 percent seed moisture and should be kept below this threshold at all times. Seeds dried below 4-5 percent moisture deteriorate faster; therefore, optimum seed moisture is probably 6-7 percent for most species. Storage below freezing temperatures subjects the embryo to ice crystal damage if the seed moisture is above the 6-7 percent level. Therefore, to be more conservative (just in case moisture is a little high in the seed), storage at about 40°F (0-5°C) is optimal. It is imperative that the seeds be stored in moisture proof containers to prevent rot and to keep the seed from imbibing moisture and breaking dormancy.

These storage recommendations will achieve the best results for most species; however, for some projects, these methods may not be achievable (remote location, lack of facilities, budget). The main message is to get the seeds dry and store them in a cool, dry place. Any deviation from these recommendations will decrease the viability of the seed.

Seeds stored at low temperatures and humidity are usually safe from disease and insect predation; however, in circumstances where storage conditions are not optimum, measures to protect the seed from fungi and insects may need to be taken. Dusting the seeds with a fungicide, such as captan, that will not damage the germinating embryo can be helpful during storage. However, this fungicide will remain in proximity with the seed during sowing and may inhibit growth of beneficial mycorrhizal fungus. The containers used to store the seeds should also be rodent and bird proof.

5.3.1.4 Evaluating Seed Viability

In order to determine the seeding rate, the viability of the seed lot needs to be determined, especially if the storage conditions have not been ideal. For some species, viability can be determined by seed color, shape, and weight. Separating seed by weight will rid the collection of empty fruits and/or inferior embryos. Viable seed can also be determined by x-ray. These methods are all non-destructive. Destructive, but definitive, methods include grow-out experiments, where a sub-sample of the seed is germinated, and tetrazolim staining, which shows differences in color between normal, weak, and dead embryo tissues. Seed testing can also be done by the L.A. Moran Center, California Department of Forestry and Fire Protection, in Davis, California.

Once the percent viability of seeds is estimated, seeding rates can be calculated (see Section 5.4.1).

5.3.1.5 Seed Pre-treatment for Germination

Germination begins with the seed imbibing water, but many species of native perennials require some type of seed pre-treatment for germination to occur. Seeds can have a physical (hard seed coat) or chemical (embryo dormancy) barrier to imbibing water, which has to be overcome before germination begins. Germination in many species is related to light exposure. In some, light triggers germination, while in others light suppresses germination. Some species have a particular light requirement, such as exposure to red light, which is the type of light that is filtered through tree leaves and eventually reaches the forest floor.

Standard methods for overcoming seed coat dormancy include scarification (scratching the seed coat—such as with sand paper or acid), stratification (placing the seeds between moist paper at low temperatures), soaking either in cold water or hot water, chilling, exposure to elevated temperatures, exposure to a certain type of light (white versus red), exposure to a specific duration of light, fluctuating temperature, chemical treatments, or any combination of these. Chemical dormancy in some species with a light requirement can also be overcome with gibberellic acid and kinetin. Leaching an inhibitor out of the seed by soaking it in water will sometimes allow germination.

The seed pre-treatment is species dependent, but observing the “life” of the seed and the plant may lend clues. Seeds with a hard coat or species that grow on dunes, such as beach pea (*Lathryus littoralis*), are likely to require scarification. Smoke tree (*Psorothamnus spinosa*), ironwood (*Olneya tesota*) and palo verde (*Cercidum aculeatum*), which are all restricted to desert washes, get scarified during flooding after a heavy rain, when they are washed downstream together with sand and gravel, thus breaking physical seed dormancy at a time when abundant water is available (Went 1953). Many desert annuals have to receive a certain amount of rain prior to germination; therefore, many of these species can be assumed to have some type of chemical dormancy requiring leaching.

In addition to experience and observation, another source of information is commercial plant growers; they may share their methods on breaking dormancy in particular species.

5.3.2 VEGETATIVE REPRODUCTION

Some species of plants do not produce adequate amounts of viable seed and need to be propagated vegetatively. Other species resprout so readily from cuttings or underground roots (rhizomes) that it is often easier to propagate these vegetatively. A little experimentation can determine which species can be or are best propagated vegetatively; usually they will be those that propagate vegetatively readily in the wild.

The best candidates for vegetative propagation are plants that produce underground stems (rhizomes), such as bulrushes (*Scirpus* spp.); plants that produce above ground, horizontal stems (stolons) from which new plants arise, such as wild strawberries (*Fragaria* spp.), sedges (*Carex* spp.) and rushes (*Juncus* spp.); or plants that can be grown from bits of stem, such as willows (*Salix* spp.), alders (*Alnus* spp.), cottonwoods (*Populus* spp.), jointed cacti (*Opuntia* spp.), and blackberries (*Rubus* spp.). Many grass species can be grown from plugs, which is a stem with a small piece of rhizome or root attached. Grass species which are grown commonly from plugs include many needlegrasses (*Nassella* spp.), dunegrass (*Leymus mollis*), saltgrass (*Distichlis spicata*), wild ryes (*Leymus triticoides* and *Leymus condensatus*), and some bluegrasses (*Poa* spp.).

5.3.3 CONTAINERIZED PLANTS

Containerized plants (commonly called "containers") are those plants grown in pots, supercells, and various sizes and shapes of containers (Figure 5.3.3a). Plants are grown in containers for a number of different reasons:

- to use species that do not produce adequate seed and do not grow readily from cuttings,
- to overcome the germination phase on a difficult or toxic site, or
- to install large sized specimens to decrease the amount of time needed to attain a required vegetative structure.

It is also much easier to achieve a desired species mixture, planting density, or planting configuration using containerized plants.

The size and shape of the container chosen should be matched to the plant's rooting strategy. Deep rooted plants should be grown in tall, linear pots; shallow, fibrous- rooted plants may need to be

A SPECIFICATION FOR SEEDS

Seeds shall be properly labeled as to genus, species, subspecies, variety, and source. Seeds shall be approved by the CDFG Representative prior to installation. Seeds shall be handled and packed in the approved manner for that species or variety, and all necessary precautions shall be taken to ensure that the seeds will arrive at the site of the work in proper condition for successful growth. Commercially supplied legume seeds shall be inoculated with a rhizobacterium known to form nodules on that species. Species of seed requiring pretreatment to germinate must be pretreated prior to application. The Contractor shall obtain clearance from the County Agricultural Commissioner, as required by law, before planting plants delivered from outside the County in which they are to be planted. Evidence that such clearance has been obtained shall be filed with the CDFG Representative prior to the work.

Photo 5.3.3a: Various container types.

grown in standard 1 gallon pots. Plants grown in tall pots produce long roots in relationship to the small above ground shoot, commonly referred to as a favorable root to shoot ratio, and usually survive better on droughty sites. An extreme example of a tall pot are those used by Joshua National Park for the outplanting of native desert species (Photo 5.3.3b).

5.4 Planting Methods

After project managers determine what species and which propagule type to use, they must decide how much to plant and how to get the plant materials on the site.

5.4.1 DETERMINATION OF SEEDING RATES

To accurately determine the amount of seed of each species required per acre the following information is needed:

1) number of seeds/pound,
2) percent purity of seeds,
3) percent germination of seeds,
4) expected survival of germinated seeds,
5) proportion of species desired on site, and
6) typical planting density of species.

Items 1, 2, and 3 are easy to calculate with the aid of an accurate balance and a petri dish; standard data can also be obtained from a seed lab. Item 4 should be based on field trials (see Section 6.7) and can be used to calculate the desired number of seeds per square foot, which can then be converted to pounds/acre. Item 5 should be based on the target vegetation surveys, and item 6 is based upon one's expertise.

Seeding rates are often given in pounds of pure live seed (PLS) per acre, which is based on percent purity and germination rates (percent viability). Percent pure live seed can be calculated from commercial or custom collected seed by the following formula:

$$PLS = \frac{PPS \times PG}{100}$$

For example, if one pound of pure live seed is desired for a species and two sources for that species are available with the following specifications:

Source A	Source B
Purity - 40%	Purity - 50%
Germination - 50%	Germination - 60%

Then Source A will have 20% PLS and Source B will have 30% PLS. Therefore, 5 pounds of bulk seed will be required from Source A to yield 1 pound of PLS, while 3.33 pounds of bulk seed will be required from Source B to yield the 1 pound of PLS. In other words, the seed application rate can be adjusted based on the preceding formula to compensate for germination or purity above or below that which is optimal.

In order to calculate bulk seeding rates for a seed mix based on PLS, the PLS needed for a

Photo 5.3.3b: Example of tall pots. Tall pots used at Joshua Tree National Park for desert restoration.

monoculture application is adjusted based on the percent of the species desired in the mix, expected survival rate, and the method of seeding. This monoculture application rate is the number that is readily adjusted by experience with the species involved. The proportion of each species within a seed mix is determined by the target vegetation surveys and the resulting species selections. For example, a target vegetation survey of an established dune community resulted in a list of the following species which would grow readily from seed: yellow sand verbena, beach bur, beach sagewort, beach morning glory, beach evening primrose, seaside daisy, seaside buckwheat, beach pea, owl's clover, coastal knotweed, goldenrod, and dune tansy. The steps for calculating the pounds of bulk seed needed for each species in the desired seed mix are outlined below in Table 5.4.1.

5.4.2 METHODS OF SEEDING

The goal of seeding is to place the seed in good contact with the soil and to cover the seed with about 1/4 inch (6 mm) of soil to protect it from desiccation and predation. The size of a project and constraints of the site usually determine the method of seeding. The least technical method of seeding is broadcast seeding by hand or using a belly grinder. Often following broadcast seeding, a chain is dragged across the site or the site is raked to bury the seed (Photo 5.4.2a). Broadcast seeding can also be done by airplane or helicopter, as is often the case following a fire, but the seeds may drift off the site under windy conditions or on steep slopes.

Photo 5.4.2a: Broadcast seeding. An example of broadcast seeding followed by chain dragging.

A rangeland drill places the seed at a specified depth in small furrows in the soil, resulting in the plants being lined up in rows—a very unnatural looking arrangement. Rangeland drills are not common in California, but are very common in the midwest (Photo 5.4.2b). Drills cannot be used on slope steeper than 3:1 (H:V) and require good access, with adequate room for maneuvering.

Hydroseeding is a common sight along California's roadsides (Photo 4.2.1b). Hydroseeding is a process by which seed, fertilizer, and a small amount of mulch, at a rate of approximately 500 pounds/acre (with or without a tackifying agent), are sprayed onto the soil surface. Hydroseeding can either occur alone or in conjunction with some type of mulching, such as hydromulching or straw mulching. Hydromulching is similar to hydroseeding, but lacks the seed and usually includes about 1500 to 2000 pounds/acre of wood fiber mulch and a tackifier. If hydroseeding or hydromulching is specified for a project, it is best specified as a two-step process: first hydroseed, then hydromulch. If instead the seed and mulch are all applied in one step, the seed may either be left

Table 5.4.1: Computation of Seeding Rates

SPECIES	SEEDS/ POUND*	% Purity	% Germination	% PLS	% In Mix	Lbs/ac in Monoculture	PLS for Mix	Pounds of Bulk Seed/ac
yellow sand verbena (*Abronia latifolia*)	20,000	95	50	47.5	20.000	30	6	12.632
beach bur (*Ambrosia chamissonis*)	34,000	95	40	38	10.000	20	2	5.263
beach sagewort (*Artemisia pycnocephala*)	1,800,000	90	90	81	5.000	0.25	0.0125	0.015
beach morning glory (*Calystegia soldanella*)	9,000	98	50	49	5.000	5	0.25	0.510
beach evening primrose (*Camissonia cheiranthifolia*)	3,800,000	80	95	76	5.000	2	0.1	0.132
seaside daisy (*Erigeron glaucus*)	1,500,000	50	90	45	5.000	0.5	0.025	0.056
seaside buckwheat (*Eriogonum latifolium*)	384,000	60	80	48	20.000	10	2	4.167
beach pea (*Lathyrus littoralis*)	6,000	98	75	73.5	10.000	20	2	2.721
owl's clover (*Castilleja purpurascens*)	11,000,000	50	50	25	5.000	5	0.25	1.000
coastal knotweed (*Polygonum paronychia*)	72,000	95	20	19	5.000	10	0.5	2.632
goldenrod (*Solidago spathulata*)	1,000,000	50	80	40	5.000	5	0.25	0.625
dune tansy (*Tanacetum douglasii*)	750,000	60	20	12	5.000	5	0.25	2.083
Total pounds/ac of seed								**31.835**

* Number of seeds/pound rounded from Pickart (1986) and Newton (1986).

Photo 5.4.2b: Rangeland drill. The Truax rangeland drill is a common tool. *Photo courtesy of Truax Inc.*

exposed to the air or in contract with the mulch rather than with the soil.

Hydroseeding and hydromulching require the use of a large tank truck, mounted with hydraulic nozzles that spray the slurries onto the site. Hoses can be attached to the nozzle to achieve a maximum reach in the neighborhood of 300 feet. This method of seeding is commonly used by the California Department of Transportation (Caltrans) and should only be used in areas with an adequate amount of moisture to promote germination (i.e., at least 12 inches (30 cm) / year). The ground surface should be moist prior to hydroseeding to ensure that the seeds will stick to the soil, and should remain moist until establishment. Hydroseeding works well on steep and inaccessible slopes, as long as the equipment necessary for the application can get access above or below the treatment area.

5.4.3 DETERMINATION OF PLANTING SCHEMATIC FOR CUTTINGS AND CONTAINERS

Determining the number of plants and the mixture of plant species to be placed on a site is much more straightforward for cuttings and containers. The only additional information necessary, besides how many of which species are needed in which areas, is the expected mortality of the cuttings or containerized plants. Mortality is generally estimated to be 20 percent; however, very favorable sites will have less mortality and difficult sites (dry, toxic, steep) will have more mortality. It is best to determine the expected mortality of the particular site during field trials prior to full-scale planting. The desired planting density should be increased by the expected mortality of each species. In addition, the spacing of the plants should be specified with a minimum number of shrubs or trees per acre (Table 5.4.3). While regular spacing of plants makes it easier to calculate densities, implement, and monitor, regular spacing (Figure 5.4.3a) is not often as desirable as a more random arrangement.

In a wetland or riparian system, close attention needs to be paid to the hydrologic needs of each species. Many riparian and wetland species are tied to a narrow moisture band (moisture regime) along the river or marsh. Observations of intact habitat can help to determine where species occur along the hydrologic gradient of a site. In the design of the plan, a schematic cross section is invaluable to depict the planting zones adjacent to rivers and wetlands (Figure 5.4.3b).

5.4.4 METHODS OF PLANT INSTALLATION

The method chosen for installing the plants on the site will vary with the propagule type and site goals.

5.4.4.1 Container Stock

Planting of container stock is straightforward for anyone who has ever gardened. Regardless of the type and shape of the container, the main requirement is to minimize disturbance of the root system while extracting the plant from the container and

A SPECIFICATION FOR MULTI-STEP COMPOST HYDRAULICALLY APPLIED AMENDMENT, John Haynes (pers comm)

All compost materials shall meet EPA 40 CFR Part 503 B regulations for pathogen and pest reduction and shall be screened to 10 mm (3/8 inch) for hydraulic application. The compost, seed, fiber, straw, and tackifier shall be applied in three separate steps. The first application shall provide 1500 kg/ha screened compost plus 400 kg/ha fiber (for other applications rates of compost, the fiber should be a minimum of 20% of the mass of compost). Seed as specified for the site shall be included in the first step. The second step involves dry application of 4500 kg/ha weed free wheat or barley straw (3500 kg/ha rice straw). The third step shall provide 2500 kg/ha compost plus 600 kg/ha fiber plus 300 kg/ha stabilizing emulsion. Any slow release chemical fertilizer required shall be included in the third step. Application of screened compost requires about one quarter of the amount of water required to apply fiber products.

placing it in the planting hole without air pockets. The first step is to overexcavate a hole to about twice the size of the plant's root ball. To provide a loose bed for the plant, dirt and any loose potting soil is then mixed in the bottom of the hole until the correct depth is attained. Slow release fertilizers, inoculum, or a scoop of native soil, can be added at this point, if desired. Then the plant should be carefully extracted from its container by gently squeezing on the sides of the container until it comes free. The root ball is cradled in the palm and carefully placed into the hole. Any remaining loose dirt should be firmly packed, but not compacted, around the plant to eliminate any large air holes that would cause the roots to desiccate. If the planting hole is very deep (augured), as for deep pots for oaks, be sure to firm up the soil in the lower portion of the hole so that the seedling doesn't subside into the hole as the soil settles. To provide greater moisture retention, the hole for the plant can be dug in the center of a basin of dirt and surrounded with a small berm. On slopes, the height of the berm can be made slightly lower than the crown of the plant, so that they don't drown during winter rains. The plant should be watered thoroughly after installation. In desert planting, the hole should be filled with water prior to planting, the water allowed to absorb into the soil, and the plant watered again after installation.

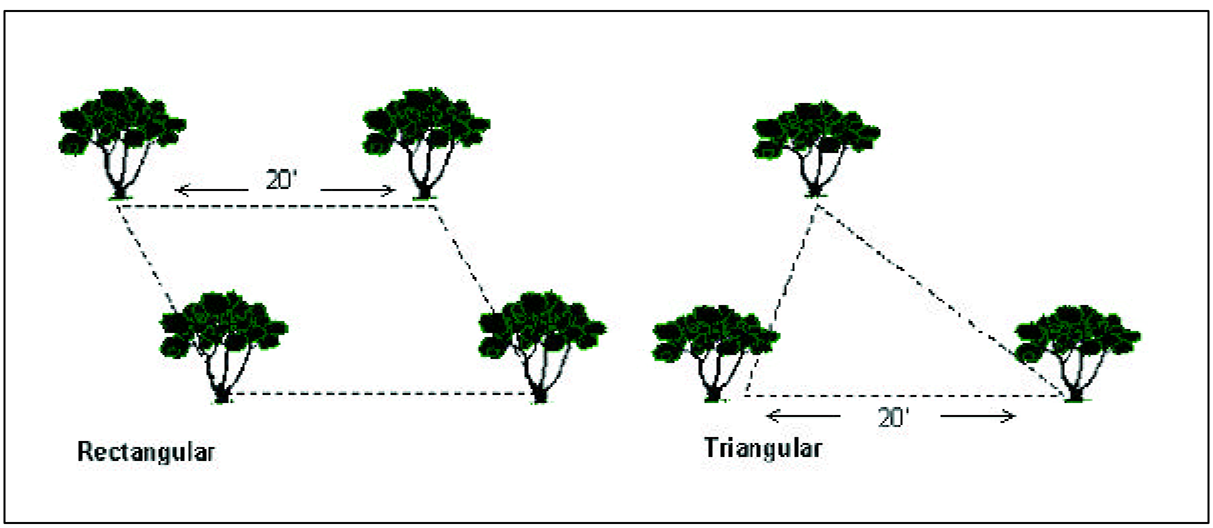


Figure 5.4.3a: Regular planting arrangements.

5.4.4.2 Transplantation

Transplantation is used when species can survive such disturbance and when larger or older stock is desired. Commonly transplanted species include willows, cactus, and various shrubs. During transplanting the key is to disturb the rooting system as little as possible; therefore, the soil surrounding the root system is usually moved with the plant. This combination of root and soil is referred to as the root ball. The most extreme example of this technique is the use of a tree spade to move large specimens (Photo 5.4.4.2). The best success with transplantation is attained if the plant is

1) moved while dormant;
2) pruned prior to moving to minimize damage to the plant, to better balance the plant, and to remove excess branches;
3) taken with a large root ball intact;
4) kept moist while moving;
5) immediately (or within one week) placed into its new location;
6) thoroughly watered-in at its new location;
7) if necessary, tethered to keep tree from toppling or leaning; and
8) protected from predation.

SPACING IN FEET	FORMULA	# TREES OR SHRUBS/ACRE	
2	43,560 / 22 (0.866) = 43,560 / 22 =	triangular rectangular	12,575 10,890
3	43,560 / 32 (0.866) = 43,560 / 32 =	triangular rectangular	5,589 5,040
4	43,560 / 42 (0.866) = 43,560 / 42 =	triangular rectangular	3,134 2,722
6	43,560 / 62 (0.866) = 43,560 / 62 =	triangular rectangular	1,396 1,210
8	43,560 / 82 (0.866) = 43,560 / 82 =	triangular rectangular	786 681
10	43,560 / 102 (0.866) = 43,560 / 102 =	triangular rectangular	503 436
12	43,560 / 122 (0.866) = 43,560 / 122 =	triangular rectangular	349 302
15	43,560 / 152 (0.866) = 43,560 / 152 =	triangular rectangular	225 194
20	43,560 / 202 (0.866) = 43,560 / 202 =	triangular rectangular	126 109

Table 5.4.3: Examples of some common plant spacings and densities.

A SPECIFICATION FOR 2-STEP HYDROSEEDING/HYDROMULCHING

If it is not possible to use a straw mulch due to steep or inaccessible slopes, the area will then receive the following treatment. Seed at the rate of 20 pounds/acre will be applied hydraulically with 500 pounds/acre (560 kg/ha) wood fiber mulch. Seeds shall not be allowed to stand in the tank (mixed with water) for more than one hour before application to the substrate. Following hydroseeding, the mulch will be applied hydraulically in one application of 1500 pounds per acre (1680 kg/ha). The slurry will be applied evenly over the site. Special care will be taken to prevent the slurry from being sprayed onto rocks and concrete structures.

A SPECIFICATION FOR SEEDING IN CONJUNCTION WITH A STRAW MULCH

All seeds to be used on the site shall be of the species specified; no additions or substitutions will be allowed. Seeds shall be thoroughly mixed and spread uniformly, either dry or hydraulically, onto the areas to be seeded at the rates specified. If seeds are hydraulically sprayed onto the site, seeds shall not be allowed to stand in the tank (mixed with water) for more than one hour before application to the substrate. If seed is spread hydraulically, it should be applied to the slopes with 500 pounds/acre of wood fiber mulch. Seeding will take place following the first application of the straw mulch and preceding the second applica-tion. The seed mix shall be applied at 21 pounds/acre. Straw mulch shall be applied as detailed in the Erosion Control Section. (This straw-intensive specification was written for a very sandy substrate.)

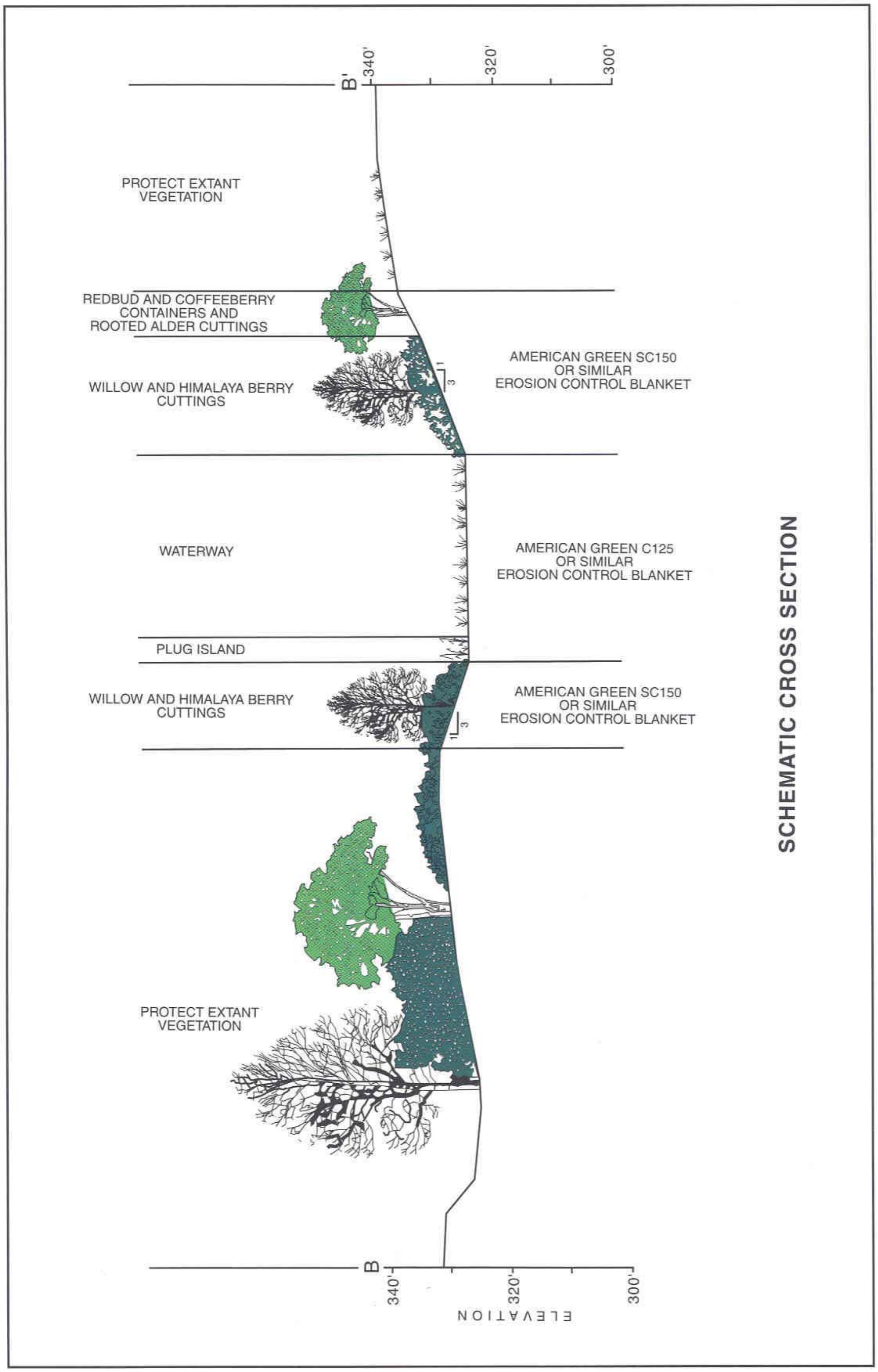


Figure 5.4.3b: Schematic cross section across a grassed waterway.

5.4.4.3 Cuttings, Sprigs, Rhizomes, and Plugs

Many different types of plant parts fall under the heading of cuttings. Cuttings can include pieces of leaf, stem, or root, and they can be rooted or unrooted. A rooted cutting has been placed in water or a very moist medium to promote the formation of roots. An unrooted cutting is taken directly from its mother plant and does not require any further treatment. Rooted cuttings are more difficult to work with than unrooted cuttings, because the new roots are easily damaged during handling and installation.

Cuttings are best taken from those species that reproduce readily by vegetative (rather than sexual) means. The most common type is a willow cutting, which is made from the stem of willow shrubs and trees. Other common cuttings include blackberry, cottonwood, alder, and grass "plugs" taken from bunchgrasses, sedges, or rushes. For the best chances of success, the following guidelines should be followed (as depicted in Figure 5.4.4.3):

1) Cuttings should be taken while the plant is dormant and planted while still dormant.

2) The cuttings must be correctly oriented (up should stay up). On woody cuttings, the base is often indicated by cutting it at a 45° angle, while the top is cut at a 90° angle.

3) Most auxiliary branches and leaves should be removed before planting; for grasses and grass-like species, the overall length should be trimmed to about 1/2 their normal height.

4) Unless they are put in cold storage, cuttings must be held no more than two weeks and kept moist.

5) The cuttings should be watered when planted to eliminate any air pockets.

6) Cuttings must be protected from predation both before and after installation.

Photo 5.4.4.2: Tree spade. Tree spades can be used to remove large specimens, while keeping the root ball intact.

Cuttings lend themselves to a special type of use called biotechnical engineering, which is the use of live plant material to create erosion control structures. Examples were given in Section 4.2.6 and include willow wattling, brush layering, brush matting, live crib wall, live silt fence, and root wad revetments. The idea behind these live structures is that the structure will physically provide the slope and soil protection needed at the earliest stages of a project. As the plants grow, the structure becomes stronger and better keyed into the slope, in the end providing slope stability, erosion control and revegetation benefits.

5.4.4.4 Handling of Live Plant Materials

Plants collected while dormant often look dead, but should not be treated as such. Live plant material, even while dormant, is subject to desiccation and physical damage. Care should be taken while collecting to maximize plant viability. The plant materials should not be allowed to dry out, should not be left in the sun, and should not be transported in uncovered vehicles. A project manager should reject any material that has been subjected to such abuses.

5.4.4.5 Plant Protection from Predation and Competition

Predation can come in many forms, from insects to cattle to humans. For success, plants installed as containers or cuttings usually need to be protected from predation and competition (Photos 5.4.4.5a

A SPECIFICATION FOR PROCURING AND INSTALLING CONTAINERS

Seeds collected for growing the containerized plants (herein termed “containers”) shall be obtained from within the defined collection region and the location shall be verified by the CDFG Representative. It is the Contractor’s responsibility to accurately identify said species and locate populations. It is also the responsibility of the Contractor to secure any and all necessary permits for collection of plant materials and to secure property owner’s permission to collect plant materials from sites. All plants furnished by the Contractor shall be true to type or name as shown on the plans; however, determination of plant species or variety will be made by the CDFG Representative and his/her decision shall be final. Plant materials shall be provided in the quantities and at sizes specified on the revegetation plans. The Contractor shall obtain clearance from the County Agricultural Commissioner, as required by law, before planting plants delivered from outside the County in which they are to be planted. Evidence that such clearance has been obtained shall be filed with the CDFG Representative prior to the work. Containerized plants shall be approved by CDFG Representative prior to installation.

Trucks used for transporting plants shall be equipped with covers to protect plants from windburn. Containers shall be handled and packed in the approved manner for that species or variety, and all necessary precautions shall be taken to ensure that they arrive at the site of the work in proper condition for successful growth.

Foothill pine, buckbrush, white-leaf manzanita, redbud, and coffeeberry shall be grown in containers from seeds collected from within the defined collection region. Installation of the containers shall follow the standard methods described below. The location, quantity and spacing of plants shall be as specified herein and as shown on the Plans or as adjusted by the engineer as necessary to meet field conditions. No planting shall be done in any area until the area concerned has been prepared in accordance with these Specifications and is satisfactory to the CDFG Representative.

1. Plants shall be grown in pots, supercells, or plant bands that have a minimum ratio of 3:1 (length:width), and a minimum height of eight inches.

2. These plants will be installed on the site between November 1 and December 1, after the onset of the winter rains.

3. Plants will be hardened-off at the nursery for one week and on the site for a minimum of one week prior to planting, a critical step especially when the environment of the growing nursery is different from the site. Immediately prior to hardening-off at the nursery, the shoot portion of the buckbrush, white-leaf manzanita, redbud, and coffeeberry (but not pine) will receive final pruning, so the resulting height of each plant does not exceed the root length. Plants will be protected from predation during hardening-off on the site.

4. A planting hole will be excavated twice as large as the rootball. The planting hole will be partially filled with loose, amended soil. A quarter of an ounce of slow-release fertilizer will be evenly spread one inch below the expected rootzone.

5. The plant will be carefully removed from the container, leaving the rootball completely intact. The plant will be examined for a healthy root system and any plants that are substandard will be discarded. The CDFG Representative will be the final judge of material to be discarded.

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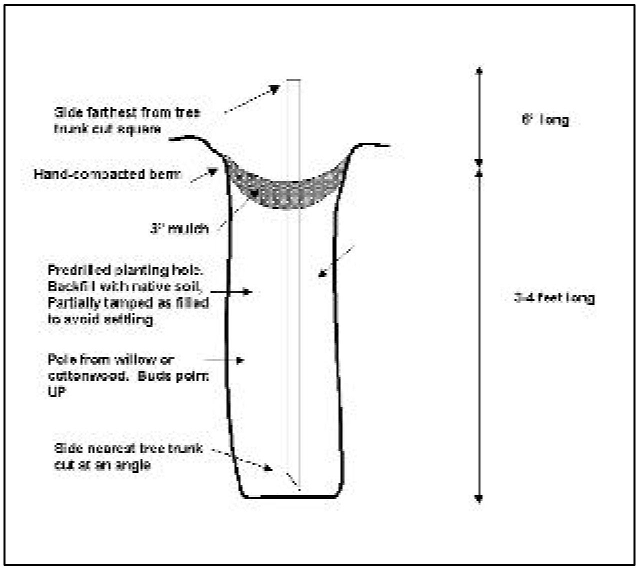

Figure 5.4.4.3: Dormant pole planting.

and 5.4.4.5b). Greenhouse plants are especially palatable to herbivores. Rodents and deer damage can threaten the outcome of a project.

The common method for protecting plants from predation is to encircle the plant with a screen, fabric, or plastic tube (tree shelter), which will keep most predators away from the new plant (Figure 5.4.4.5). If burrowing rodents are a problem, then belowground cages will help to protect the plants. A raptor perch overlooking the rehabilitation site may attract raptors that will help to keep the rodent population in check. As the plant grows outside of the protective shelter, browse is likely, but should not be detrimental at this point in the plant's life cycle. Protection of plants from humans usually requires appropriate signage, and perhaps some type of exclusionary barrier, such as boulders or fences.

In California, competition usually comes from introduced exotic species, especially annual grasses. To protect the plant from competition, methods are used that keep a "no-grow zone" around the base of the plant. This zone is created by a deep mulch (such as wood chips), black plastic sheeting, or a weed-stop mat. Some rehabilitation sites have used pre-emergents (chemicals that surpress germination) or herbicides to minimize the amount of competing

A SPECIFICATION FOR PROCURING AND INSTALLING CONTAINERS...continued

6. The plant will be placed into the planting hole and the soil firmed around the plant to bring the soil to slightly above the root crown at finished grade. Plant shall be encircled with a planting collar (one quart container with bottom cut out). Weed-stop mats will be placed around the base of the plants and tucked under the planting collar to limit the establishment of competing weeds. A mulch layer, four inches thick of weed-free wood products, may be substituted for the weed-stop mat at the discretion of the CDFG Representative.

7. The plants will be placed in soil depressions or collection basins to increase the amount of precipitation intercepted by the plant and "watered-in" at the time of planting. On slopes, a four-inch high, hand-compacted earth berm will be constructed along the forward edge of the planting terrace for a watering basin. Immediately after installation, the plant will be irrigated to settle the soil around the plant. If the root becomes exposed, additional soil will be placed around the root crown.

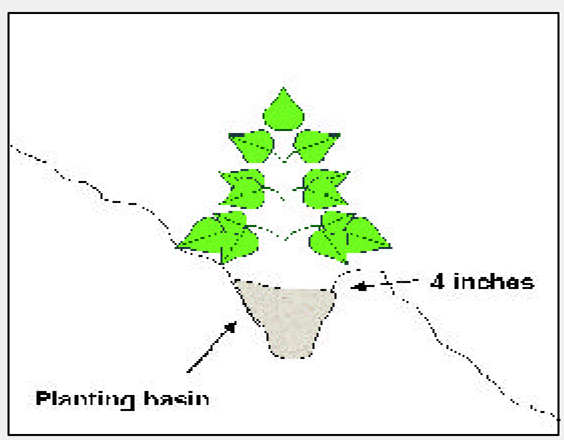

Photo 5.4.4.5a: Riparian restoration site before project. Cattle damage caused soil compaction and loss of stream-side vegetation.

Photo 5.4.4.5b: Riparian restoration site five years after implementation. Soils and stream-side vegetation recovered after restoration techniques were implemented.

Photos courtesy of Redwood Community Action Agency.

weed species prior to project implementation. Other projects have instituted a controlled burn prior to planting to reduce weed competition. Both the use of chemicals, such as pre-emergents and herbicides, and the use of fire are regulated and require local permits. As an alternative to burning, mowing during the correct time of year may reduce exotic annuals while it avoids the risks posed by a controlled burn.

5.4.4.6 Storage/Hardening-off Facilities

Live plant material, such as cuttings and plugs, often need to be stored, on or off the site, prior to planting. The goal is to store the material in a location that will keep them from drying out. Cuttings can be stored in moist newspaper or wood pulp in plastic bags in a cool location. Plugs can be heeled-in (that is, held over and kept alive) on the site by digging a trench in a shady, moist location, placing the plants in the trench, and backfilling the trench until the plants are approximately half buried.

Plants that have been grown in the greenhouse have had a luxurious life of water, shade, and nutrients, all in abundance. These plants can go into shock when placed out on a dry, harsh site. Therefore, plants are usually "hardened-off" (weaned of frequent waterings and nutrient supplements) prior to installation on the site. This procedure requires that the plants be taken to the planting site to become climatized. Often a shady location is used or shade structure erected to house the plants, and measures (such as a fence) are installed to protect the plants from predatation. For especially harsh sites, it is often beneficial to ask the grower to stress (minimize nutrient supplements and waterings) the plants during grow-out, in essence hardening them off for a much longer period of time.

5.4.5 NURSE CROPS

Nurse crops were once commonly used on sites to control erosion and create shade for the desired species. However, nurse crops are seldom used with native plant revegetation in California, because they often compete with the desired species by increasing nutrient and water stress. Nurse crops used on some projects have persisted and eventually replaced the desired plant community. The beneficial effect of a nurse crop can be mimicked with the use of a punched straw mulch, as discussed in Section 4.2.1. Recently, sterile hybrids have been used as a nurse crop, thereby limiting the disadvantages of the nurse crop to two or three years. Examples of these sterile

> **A SPECIFICATION FOR CACTUS TRANSPLANTING**
>
> Transplanting shall take place between August 1 and March 1. Each cactus shall be transplanted with at least six inches of its primary root intact. Standard techniques will be used for transplanting these individuals, which include
>
> - marking, in some noninjurious manner, the north side of each individual prior to removal;
> - storing the cacti in a shaded area for at least two weeks to allow bruised roots to heal;
> - returning the cacti to the site within three months after removal and replanting in the proper compass orientation in a soil depression; and
> - watering the cacti immediately following planting with two gallons of water treated with vitamin B-1 (for root growth).

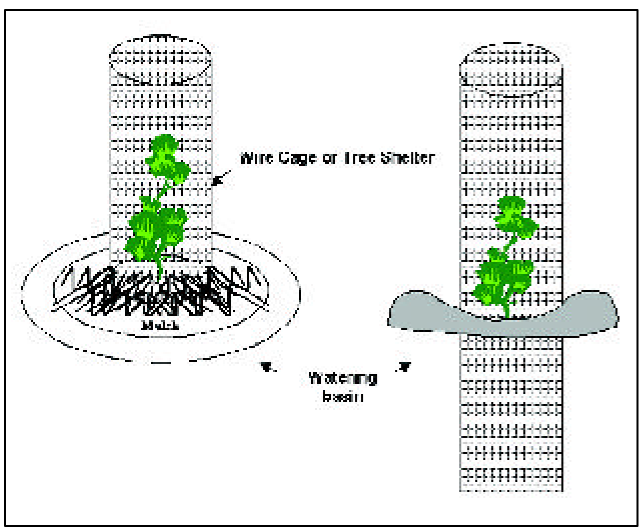

Figure 5.4.4.5: Plant protection.

A SPECIFICATION FOR PROCUREMENT AND INSTALLATION OF CUTTINGS

Cuttings shall be obtained from within the defined collection region and the location shall be verified by the CDFG Representative. It is the Contractor's responsibility to accurately identify said species and locate populations. All plants furnished by the Contractor shall be true to type or name as shown on the plans; however, determination of plant species or variety will be made by the CDFG Representative and his/her decision shall be final. Cuttings shall be approved by the CDFG Representative prior to installation.

Trucks used for transporting plants shall be equipped with covers to protect plants from windburn. Cuttings shall be handled and packed in the approved manner for that species or variety, and all necessary precautions shall be taken to ensure that the cuttings will arrive at the site of the work in proper condition for successful growth. The Contractor shall obtain clearance from the County Agricultural Commissioner, as required by law, before planting plants delivered from outside the County in which they are to be planted. Evidence that such clearance has been obtained shall be filed with the CDFG Representative prior to the work. Cuttings shall be planted not more than one (1) week after cutting off the mother plant and shall not be allowed to dry or wither. Rooted cuttings, i.e., alder, shall be planted not more than two months after collecting and shall not be allowed to dry or wither.

1. The collection of willow and alder shall be done from populations located on Little Dry Creek. The willow and alder that will be removed during construction from Little Dry Creek can be excellent propagation material if removal for construction coincides with the plant's dormancy and the revegetation schedule.

2. Willow and alder cuttings shall be taken from large vigorous-growing shrubs and trees soon after leaf drop in the late autumn and prior to bud swelling in early spring.

3. Willow and alder cuttings shall be made from healthy individuals. Length of cuttings shall be a minimum of 18 inches; width of stem shall be a minimum of 0.5 inches at cut base, but may be as large as 6 inches. The base cut shall be made at approximately a 45-degree angle to the stem. Cuttings are to be bundled in lots of 25 to 50 each with the basal ends oriented in the same direction. If the terminal end is cut, cut horizontally to aid in keeping cuttings oriented correctly and to facilitate planting.

4. If it is necessary to store cuttings prior to planting, they shall be wrapped in moist newspaper with dry newspaper covering, or in plastic bags with moist sawdust. Willow cutting shall not be stored longer than one week, unless stored off-site in a standard cold room.

5. Alder cuttings will be transferred to a water bath to promote rooting. Alders will remain in the bath no longer than two months, and be transported to the site while wet.

6. Bundles of cuttings or individual cuttings shall be treated immediately prior to planting with a rooting hormone and fungicide, such as hormodin powder, by dipping the basal 3/4 of the cuttings. The bundled cuttings should be allowed to dry for 30 minutes to an hour in open air prior to planting. This minimizes loss of the rooting hormone through handling and planting, thus increasing the success of root initiation. Cuttings shall be kept out of direct sunlight until ready to plant.

...continued on next page

hybrids includes a wheat X wheatgrass cross with the commercial trade name of Regreen.

5.5 Irrigation

Irrigation can take many forms and the need for irrigation is project-specific. For most wildland plants that are installed during the correct season, irrigation is unnecessary and can cause many problems. Frequent and shallow irrigation can cause root rot and can promote shallow root development, which will leave the plant roots above the moist soil zone when the irrigation is removed. Infrequent irrigation that mimics normal rain patterns can aid in plant establishment on harsh sites. The need for irrigation should be carefully examined.

If containers or cuttings are used, they need to be "watered-in" at the time of planting. The addition of water to the planting hole helps to eliminate any large air spaces that would cause desiccation. This type of irrigation is standard and should be used for all containers, transplants, or cuttings.

The establishment phase (the first, and perhaps, the second growing season) for containers, transplants, and cuttings is when most mortality occurs, much of it caused by inadequate soil-moisture. To aid plants, supplemental water is often applied during the establishment phase. Watering basins are usually formed around the plant to direct water to the new plant and to aid in infiltration of water near the root system. In the wetter climes of California, a berm can be constructed 1-2 feet down-slope so that ponded water does not cause stem or root rot. The frequency and amount of water is determined by sampling the soil throughout the site and by observing the plant responses. The goal is to add enough water to aid in establishment without making the plants dependent upon the additional watering in the long-term.

A full-scale irrigation system has been used on various projects. These systems resemble golf course systems and often promote the growth of undesirable species. The best strategy for using standard irrigation designs is to forego the automatic clock and irrigate infrequently (i.e., only when needed), mimic the natural rain cycles, and irrigate longer to allow for deeper infiltration.

A SPECIFICATION FOR PROCUREMENT AND INSTALLATION OF CUTTINGS ...continued

7. The cuttings shall be placed through the erosion control blanket and into the substrate such that a maximum of 4 inches remains above the substrate (planted at least 14 inches deep). The holes shall be closed using the heel of the boot applied in such a manner as to close the hole completely around the cutting. No airspace shall be left. Irrigate the cutting immediately after installation to settle the soil around the cutting. If the base becomes exposed, place additional soil around the cutting.

A SPECIFICATION FOR PLANT PROTECTION

Containerized plant materials and cuttings are usually very palatable to wildlife and insects and will need to be protected from predation; therefore, each cutting or container (with the exception of blackberry) will be encircled with a fine-mesh wire tube or tree shelter at the time of installation. Cages constructed around the shrubs will be of sufficient size to allow the plants to grow without being restricted by the cages. Cages can be constructed of fine-mesh wire, or standard light-colored tree shelters can be used. Cages shall be secured to the planting collar, if applicable.

One last problem may be associated with the use of irrigation: water quality. While use of an on-site water source is desirable for irrigation, one needs to be cautious. A water sample should be taken to a lab and analyzed for pH, electrical conductivity, and heavy metals. The water quality in the vicinity of mine sites may be detrimental to plant growth, either because of the proximity of a heavy mineralized zone or because of water impacts caused by mining. If any doubts exist about the quality of the water, good-quality water should be obtained by an outside source and either pumped or trucked to the site.

5.6 Inoculation with N-Fixing Bacteria or Mycorrhizal Fungi

Nitrogen is often the growth-limiting factor on sites in California. While there is ample nitrogen in the air, it is not in a form available to plants to affect plant growth. Some species have nitrogen-fixing bacteria associated with their root systems that convert N_2 to plant available forms. Most legume species fix nitrogen (such as *Lupinus*, *Lotus*, and *Vicia*), as do alders (*Alnus*) and ceanothus (*Ceanothus*). Therefore, the planting design for most projects will include nitrogen-fixing species to minimize the need for continued nitrogen fertilization. However, it should be noted that Marquez and Allen (1996) found that annual legumes did not increase total soil nitrogen, and were competitors for resources and detrimental to the survival of the desired native species. If seed or plants are purchased commercially, it should be specified that these materials will arrive to the site inoculated with the appropriate bacteria. Material collected from the wild can be inoculated by transplanting the root system or inoculating the site with soil from the wildland source near other, similar nitrogen-fixing species.

Most California native plants have symbiotic relationships with mycorrhizal fungi, which greatly increase the growth and survival rate of the plant. While the effect is often not visible on favorable sites, the effect can be dramatic on low nutrient sites. These fungi colonize the root of the host plant and branch out into the soil matrix, putting the plant in contact with a much larger volume of the soil than would otherwise be possible. This enlarged soil reservoir increases the nutrient and water uptake ability of the plant. It is believed that this is especially advantageous for phosphorus uptake, since this macronutrient is not mobile in the soil. Mycorrhizae may also increase the plant’s tolerance to low pH and to high heavy metal concentrations in the soil.

It may take over five years for natural reinvasion of mycorrhizal fungi to achieve a level of colonization necessary for overall plant response on sterile substrates (Greipsson and El-Mayas 2000). Therefore, some type of manual reintroduction may be warranted. Recent advances in mycorrhizal technology have made available inoculated containerized plants and direct application of inoculation to soils. Nurseries should be able to document the colonization percentage of stock, or the propagule density of inocula. A low tech, inconclusive methodology for introducing mycorrhizae to a site is to transplant soil from the roots of plants on an adjoining, undisturbed site. In general, a plant growth response from mycorrhizal inoculation is most likely to be observed at sites with low to moderate fertility and where no mycorrhizal plants already grow (such as previously fumigated or newly excavated areas or areas with predominantly non-mycorrhizal species such as chenopods, amaranths or mustards).

5.7 Fertilization

Standard labeling on commercial fertilizers provides a quick reference for the amount of the macronutrients nitrogen, phosphorus, and potassium in the fertilizer. The percentage of nitrogen (N), phosphorus (P), and potassium (K) by weight is provided as a three number designation (the N-P-K number) and is listed in that order on the fertilizer bag. Sometimes a fourth number is given for sulfur. Therefore, if 5 pounds of pure nitrogen is needed, then 50 pounds per acre of a fertilizer with 10 percent nitrogen must be applied. While N is calculated as a straight percent by weight of nitrogen-N, the P content of the fertilizer is expressed as percent by weight as P_2O_5 which is 2.29 times greater than elemental P. To get the P contained in the fertilizer dose, multiply the weight of fertilizer applied per area times the percent formulation on the bag and divide by 2.29. Similarly, K in the fertilizer is expressed as K_2O which is 1.205 times greater than elemental K.

Fertilizers fall into two groups, fast-release formulations and slow-release formulations. The fast-release fertilizers are full of available nitrogen, which is released by the first rain following application and persists on the site for up to three months. Fast-release fertilizers are excellent for growing invasive annual grasses and other weeds, but of little use for native plantings. Common formulations are 21-0-0 (ammonium nitrate) and 16-20-0-13 (ammonium phosphate sulfate). Being rich in nitrogen, these formulations favor top growth (leaves and shoot) over root growth.

Slow-release fertilizers will stay on a site for nine months to two years, depending on the climate at the site. Some materials are broken down and released by microbial activity, but others release by dissolving in the pore water of the soil. Some have resin coatings that breakdown and release nutrients. The longer duration release patterns are achieved by encoating the fertilizer granule in a thin plastic layer. Slow-release fertilizers release the nutrients at a pace more in tune with native plant needs. Use of a small amount of slow-release fertilizer on a rehabilitation project can help support the plants while the soil is recovering from stockpiling and can be used to feed the microorganisms that break down mulches. Slow-release fertilizers come in many different formulations, but the most commonly used on rehabilitation projects are those that are balanced: 13-13-13 and 20-11-12 plus micronutrients. Standard application rates for rehabilitation projects vary from a low of 25 pounds/acre to as high as 200 pounds/acre.

Fertilizer is commonly broadcast on the surface of the site, either alone (by hand) or as part of the seeding operation (included in the hydroseeding). Another beneficial use of fertilizer is to put a small amount at the bottom of planting holes, thereby putting it out of the reach of the exotic annuals, but within the reach of the native plants.

Prior to the 1980s, fertilizer was recommended for all projects at rates as high as 500 pounds/acre. These recommendations were based on revegetation projects that were largely associated with agriculture or whose sole purpose was erosion control (transportation corridors). As the use of native plant species became more popular, it became obvious that fertilization was often not necessary and could be detrimental to project goals. Fertilization (and irrigation), while beneficial if used sparingly and correctly, can favor weeds over the desired native species if used without discretion.

6.0 PERFORMANCE STANDARDS AND MONITORING

The time to begin designing a monitoring program is during the initial concept stage. Monitoring should be conducted prior to the implementation of a project to assess the baseline conditions or to assess the conditions of a reference site (baseline monitoring), during the implementation of the project to determine if the project was constructed as designed (implementation monitoring), following the completion of the project to determine if the project had the desired effect (effectiveness monitoring), and through time to determine if the assumptions behind the project were valid (validation monitoring). Various levels of knowledge are needed for each level of monitoring. For example, implementation monitoring should be conducted by a qualified individual (or team) that is able to make on-the-job adjustments to the project design, such as changes in a grading plan, soil amendment plan, planting design, and species specifications, and able to communicate those changes to the project contractors. Following implementation, the project plans and specification should be altered by this individual to reflect any changes that were made during construction; these final plans are often called "as-builts." The remaining sections will emphasize effectiveness monitoring.

A rehabilitation plan must include performance standards that make clear to all parties what will be considered successful rehabilitation, especially if some type of financial assurance (bonding) is tied to the outcome. While a picture may be worth a thousand words, photographic monitoring (that is, photographing the site from the same vantage point on a yearly basis) does not provide quantitative performance measures, and should, therefore, be used only in conjunction with quantitative monitoring. In addition, the plan must lay out a program of monitoring that keeps track of what is happening on the site after implementation. Monitoring provides data that can be compared against the performance standards to determine the degree of the project's success. Equally important, a monitoring program helps determine when or if maintenance or remedial measures might be needed. Maintenance activities are planned activities, both short-term and long-term, that are undertaken to maintain plants or structures as originally designed and installed on a site. Remedial measures are intended to correct adverse circumstances and to get the project site, or a portion of it, back on the path of achieving project goals; such measures may be planned for in anticipation of possible failures or they may be added, post-construction, to the project to deal with unforeseen circumstances. A further purpose of monitoring is to gather data for reporting the outcome of the project in order to fulfill permitting obligations. Finally, the data from monitoring helps further the science and art of ecological restoration.

In addition to specifying the performance standards, laying out the monitoring program, describing any maintenance activities, and providing for the possibility of remedial measures, the rehabilitation plan should identify the responsible parties and funding for each of these activities. Without these responsibilities determined at the start, it is likely that neither monitoring nor maintenance will happen.

Many books have been written on the subject of monitoring; therefore, this section will briefly cover the most common and easiest of methods for mined-land reclamation. An excellent reference for monitoring, which was recently published (1998) by the Bureau of Land Management and the Nature Conservancy, is *Measuring and Monitoring Plant Populations*, by Caryl L. Elzinga, Daniel W. Salzer, and John W. Willoughby.

6.1 Establishment-Phase Monitoring vs. Long-Term Monitoring

Often the effectiveness monitoring of a project is divided into the establishment-phase monitoring and the long-term monitoring. Establishment-phase monitoring is a time of intensive, qualitative monitoring with subsequent adjustments to the rehabilitation design. Small acts of intervention, such as additional fertilization or irrigation, during the establishment phase can prevent huge expenditures of time and money later. Establishment-phase monitoring should begin immediately following planting and continue monthly until the plants have become established, usually in the first growing season. As a first measure, the project manager should check for appropriate installation of the containerized plants and see that the planting design has been implemented correctly. Quantitative data collection may not be needed for subsequent establishment-phase monitoring, but careful observations of plant health, pests, herbivory, drought, and excessive erosion are required. Often a financial assurance will not be released until a project has successfully passed the first season of monitoring.

For long-term monitoring, a graduated monitoring schedule (more frequent monitoring in the first few years, less frequent in later years) may provide adequate information about the site while keeping monitoring costs at a minimum. For example, a project could be monitored twice a year the first year, once a year for the second and third years, and then on two-year intervals until year ten. The following sections discuss performance standards, monitoring, maintenance, and remedial measures that may be applied to various aspects of a rehabilitation plan.

6.2 Performance Standards for Vegetation

Performance standards should be developed such that they form both the basis on which the outcome of the rehabilitation project is judged and set the thresholds that determine whether or not remedial measures are needed. Thus a project may have a set of performance standards, projected to five or more years in the future, which represents the goal of the project, and it may also have a set of interim standards which, if not met according to schedule, will trigger remedial measures. These interim standards and their respective remedial measures should be determined prior to project implementation. For each parameter included in the performance standards, the minimum area (acreage, square feet, hectares) to which that standard will be applied should also be stated.

6.2.1 SETTING PERFORMANCE STANDARDS AND MONITORING FOR PERFORMANCE STANDARDS

Performance standards can be set based on either external standards or internal standards or both. External standards come from local ordinances or other laws and regulations; internal standards are developed to meet specific conditions of the project and are usually based on baseline data or on data from a reference site. The State Mining and Geology Board (SMGB) Regulations (Article 9) uses both methods by allowing a reclamation plan to set forth its own revegetation performance standards, while stipulating what will be sampled: cover, density and species richness.

The sampling methods for developing the internal standards are the same as the sampling methods for monitoring the site after implementation. Thus, this discussion will cover both these aspects of the rehabilitation plan.

When project managers are faced with developing standards and monitoring plans, they most commonly ask the following questions about sampling:

- How do I choose a reference site, what do I sample, and where do I sample?
- What size plot do I use?
- How many samples (plots) do I need?
- What type/shape of plot do I need?
- How do I lay the plots out on the site?
- When do I sample the plots?

The following discussion provides guidance on these questions.

6.2.1.1 Selecting a Reference Site

Ideally, a project manager will have access to the site that is to be eventually rehabilitated before the proposed project disturbs the site. Such access will allow the gathering of baseline data to be used as performance standards for revegetation after disturbance. However, many projects do not have the benefit of baseline data,

AN EXAMPLE OF PERFORMANCE STANDARDS (CHAMBERS GROUP, INC. 1995)

"All plantings for the upland and riparian revegetation communities will have a minimum of 80 percent survival the first year and 97 percent survival thereafter for 4 additional years. If the survival and growth requirements have not been met, then Mission Viejo Materials is responsible for replacement planting to achieve these requirements. Replacement plantings will be monitored with the same survival and growth requirements for 5 years after planting. If performance standards are met by the fourth year after planting, maintenance and monitoring activities can be negated if and only if justified and accepted in writing by CDFG."

often because the vegetation of the site has long since been eradicated. Or the project may seek to create a type of community structure that did not previously exist on that specific site, such as a wetland in an upland situation. For these types of projects, it is important to choose an appropriate reference site.

The reference site should match the environmental and edaphic conditions of the project area: it should be located as close to the project site as possible, within the same elevational range (perhaps ± 500 feet), on the same type of soil, and with the same aspect and climate. In addition, the reference site should match the target vegetation proposed for the project area: it should be dominated by the same type of vegetation, habitat, structure, and species composition. In other words, the guidelines for selecting a reference site are similar to those for selecting a site to collect plant material for revegetation on the project (see Section 5). If time and money allow, inspection and sampling of more than one reference site can give the researcher an idea about the amount of variability in the target vegetation type.

6.2.1.2 Stratifying the Sampled Area

A small site where uniform soil and vegetation cover are the same poses few problems about where to sample. If, however, a site has, for example, a grassland and woodland component (Photo 6.2.1.2), then these components need to be sampled separately. That is, the site must be stratified into the two component areas and then sampled. Such stratification may be necessary both in sampling a reference site and in monitoring the rehabilitated site. For example, a mine site that has an area of alkaline soils and an area of acid soils will have different soil treatments applied to the different soil types during rehabilitation. When monitoring these areas, the mine site will have to be stratified into two components based on the soil type, with each component sampled separately. Performance standards will likely vary by strata as well, as by vegetation type or treatment area. The number of areas that have to be sampled separately can become quite numerous on a large and complex site.

Many vegetation types are made of different layers of vegetation, with, for example, trees standing above shrubs and herbs growing beneath both trees and shrubs. Depending on the site, the different layers may require different sized plots, as well as being assessed separately.

6.2.1.3 Determining the Appropriate Size of the Sample Plot, the Species-Area Curve

The sampler is interested in a plot size in which the species composition of the community is adequately represented, homogenous, and unfragmented. If the area being sampled is not homogenous, the area should be stratified into smaller units that are homogenous and then each area sampled separately.

The smaller the sample area (plot size), the easier to count or measure individual plants and to measure or visually estimate cover. However, the plot needs to be big enough so that the variation between the plots is minimized. The trick is to pick the smallest plot size for a particu-

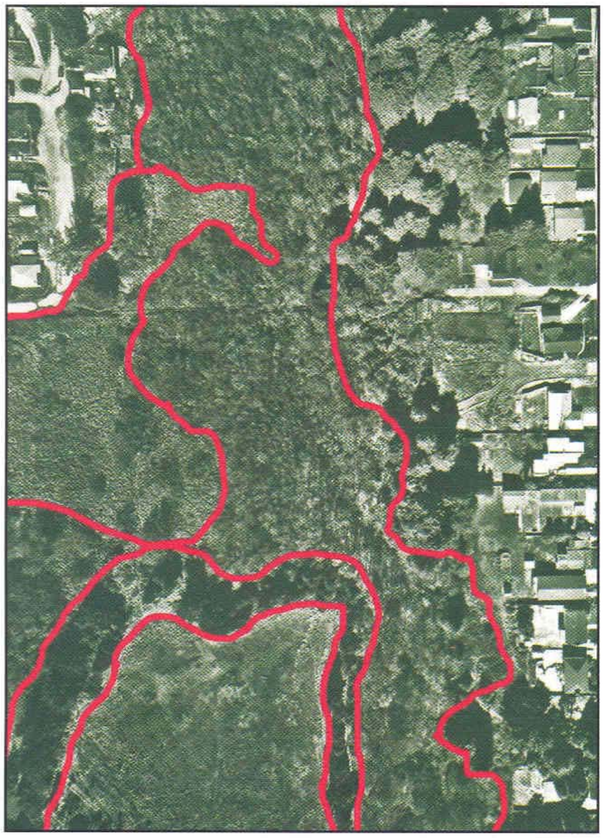

Photo 6.2.1.2: Example of stratifying an area. Aerial photograph of a grassland/wetland/woodland complex, stratified into homogenous sampling units.

lar vegetation type that will still keep the variation between the plots low.

The minimum area of the plot is determined by progressively sampling larger and larger areas and plotting the cumulative total number of species by the size of the plot. For example, a plot of $0.25 m^2$ may be sampled and yield four species. A plot twice that size ($0.50 m^2$) may then yield four additional species (cumulative = 8). A plot twice that size ($1 m^2$) may yield only two additional species (cumulative = 10), and so forth, until the number of species added to the list becomes very few (Figure 6.2.1.3a). The cumulative numbers of species (i.e., 4, 8, 10, 11, 12) are then graphed by the plot size ($0.25 m^2$, $0.50 m^2$, $1 m^2$, $2 m^2$, $4 m^2$). The minimum sampling area can be visually estimated as the point at which the curve levels off, $1 m^2$ in Figure 6.2.1.3b. Other considerations in determining the size of the plot are cost, available time, and ease in estimating parameters (e.g., cover or density). Table 6.2.1.3 provides general recommendations for plot size based on vegetation type.

6.2.1.4 Determining the Number of Plots Needed to Achieve an 80% Confidence and Precision Level

Determining the number of plots needed to adequately sample an area with an 80% confidence and precision level, as required by Article 9 of SMGB regulations, is an iterative process. The statistical formula for the required sample size on normal data follows, where n=the sample size needed, t^2 is the Students' t value for the sample (available in most standard statistic references), s^2=the variance, and x=the sample average:

$$n = \frac{t^2 s^2}{(.20x)^2}$$

Many people would rather not go through this exercise, and often vegetation data has a nonnormal distribution, which therefore renders the above equation useless. In this case the sample size for nonnormal data can be based on probability theory alone and yields a minimum

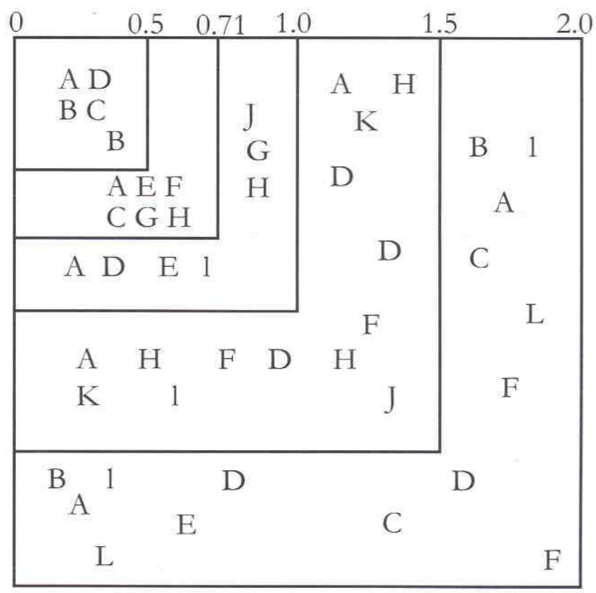

Figure 6.2.1.3a: Determining plot size by progressive sampling, with letters representing species and measurements in meters.

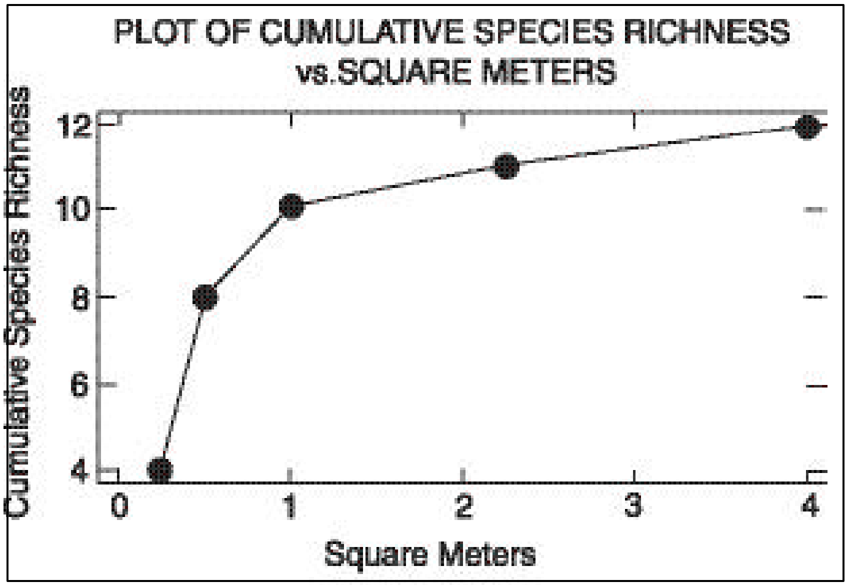

Figure 6.2.1.3b: Species-Area Curve: A plot size of 1m² would be the most efficient size for this example.

sample size of 38 at 90% and 14 at 80% confidence and precision level. Therefore, a researcher who wishes to forego any calculations, while still achieving an 80% confidence and precision level, could probably use a sample size of not less than 14 sample plots for most vegetation types, assuming the sampling frame (plot) is of adequate size.

6.2.1.5 Determining the Shape of the Plot

Plot shapes can be a circular, rectangular, square, or a linear belt (belt-transect). (There are also "plotless" methods of sampling which will not be discussed here, but which are also appropriate for certain types of measurements.) Of course, the choice of plot shape (and size) can greatly affect the amount of time it takes to sample a site, so a major consideration should be ease of use.

Smaller plot sizes are easier to use, especially if the site is remote or large and some hiking is required to carry a sampling frame around. Circular plots are easier to use because they don't require the carrying of a sampling frame; a circle can be drawn on the ground with a stake and a length of string. However, rectangular plots are more efficient (i.e., reduce the variance) than either circular or square plots (Greig-Smith 1964). The larger the plot the more time it takes to determine the boundaries of the plot. Therefore, the shape of frame is often based on ease of determining boundaries: smaller plots are often 0.5 m^2 rectangles or 1 m^2 squares and larger plots are often belt-transects with dimensions such as 10 meters by 0.25 meters.

6.2.1.6 Determining Where to Put the Plots

Plots should be located randomly within the site or the portion of the site to be sampled. The issue here is not to bias data collection by purposely oversampling or undersampling certain areas. To truly randomize a sample regime, however, takes time and may omit sampling areas important to project goals. In addition, highly localized species, highly localized vegetation types, and rare species are often missed by random sampling. Thus, researchers more commonly employ some type of stratified random sampling technique.

As previously explained, to stratify an area means to divide the larger area into small areas of homogenous, representative stands. The ecotones, or areas between the stands, are avoided. Then within each homogenous area, the location of plots is randomized. Often a random point is chosen by simply throwing a marker into the area to be sampled. Does this mean that the location of each plot has to be independently determined? This is an area of active debate. Some researchers say that each plot must be determined independently in order to assure random samples; others assert that as long as the first sampling point is located randomly, then all points located using that reference point, perhaps by using a pattern, are random as well (e.g., randomly selecting the location of a line transect and then methodically measuring plant parameters in quadrats at equally spaced distances along that transect). The latter interpretation is conveniently accepted in the examples in this section because it makes sampling easier.

VEGETATION TYPE	PLOT SIZE RANGE (most common)
Grassland or Herb Layer	0.25-2 m^2 (0.5 m^2 or 5 ft^2)
Shrubland or Shrub Layer	4-16 m^2 (10 m^2 or 100 ft^2)
Forest (tree layer only), or Sparse Desert Vegetation	100-314 m^2 (100 m^2 or 0.1 ac)

Table 6.2.1.3: Suggested plot sizes (from Bonham 1988 and Mueller-Dombois and Ellenberg 1974).

6.2.1.7 Determining What Time of Year to Sample

Establishment-phase monitoring should begin immediately after implementation, regardless of the season. The long-term monitoring may be delayed until the appropriate growing season. In order for the data to be comparable across the years of sampling, such long-term monitoring must be done at the same time of the season each year. The best time to sample a site is near the end of the active growing season for the dominant plant species or for the species of interest. For the lower desert regions, this will be approximately April and May (which means that many of the annual species will be missed). For the higher elevations, the best time to sample may be as late as August. But for the majority of areas in California, the months to sample vegetation are usually June and July. Reference site sampling should also take place during the appropriate growing season; allowing time for sampling at the correct time of year requires careful planning well ahead of the implementation of the project.

6.2.2 SAMPLE PARAMETERS

The three sample parameters required by Article 9 of the SMGB regulations are cover, density and species richness. These parameters are used during the reference site sampling, as well as during the rehabilitation site sampling. In addition to these, it may be helpful to include growth and mortality monitoring on species installed as containers or cuttings. Projects not governed by SMARA may require other parameters such as diversity, nutrient cycling, and wildlife usage, which will not be discussed here.

When reporting results, each sample parameter should be expressed as a sample size, a mean (average) value, a range of values, and a variance. These statistics will require some simple math, which can be done on a statistical calculator. A sample data collection sheet for monitoring vegetation is included in Appendix B.

6.2.2.1 Cover

Cover is defined as the downward vertical projection of the crown or shoot area to the ground surface, expressed as a percentage of the reference area. Another way to describe cover is as the percentage of the ground area in the sample site that would be obscured by the vegetative crown if the site were viewed from above (Figure 6.2.2.1). Cover can be estimated or calculated separately for target species or for all species together (total cover).

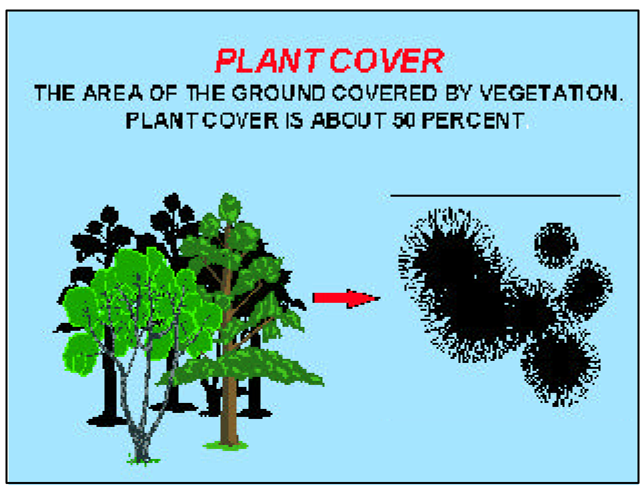

Figure 6.2.2.1: A definition of cover.

STATISTICS

Just the word alone scares most people, but statistics are necessary for perform-ance monitoring. Many books are available on basic statistics and the assumptions underlying those statistics. Most spread-sheet programs include basic statistical calculations, as do most calculators. So it is not necessary to know the formulas behind the calculations, just which results to report, what they mean, and the assumpt-ions underlying the calculations.

Standards usually are set at one number, say 80% survival. If you count the number of individuals surviving on your project and only 78 survived out of the 100 planted (i.e., 78% survival), does that mean that you have not met the 80% standard? Actually, it is very likely that you have met the standard and even an average of 75% survival, as depicted in Figure 6.2.2.5 is not significantly different from the 80% standard. That is, the 80% confidence intervals on the mean of 75% overlap with 80% as shown in the graph. And often graphs, as depicted in Figure 6.2.2.5, are the best way to present the data.

The measurement of cover does not require that the observer be able to identify individual plant species, or even discern individual plants, and is, therefore, very useful in grassland situations. Experienced researchers usually estimate cover visually. Inexperienced individuals should measure the amount of cover using a densiometer or a partitioned quadrat, or a tape measure. The latter of these methods would, for instance, require the researcher to mark off the area being sampled, e.g., 100 square feet. Within that 100 square feet, each shrub would be measured by laying a tape measure across the crown of the shrub in two different directions, calculating the average diameter, and then determining the area of that circle (πr^2). If the area comes out to, for simplicity's sake, 7 square feet for each shrub, then the cover of each shrub would be expressed as a percentage of the 100 square foot plot, or 7%. For this example, if a plot has seven shrubs, each making up 7% cover, the plot would have 49% cover by vegetation and 51% bare ground. This calculation assumes that the crowns of the shrubs do not overlap. If the crowns of the seven shrubs overlapped, then even though each plant represents 7% cover, the total plot cover would be less than 49% (i.e., diminished by the amount of overlap).

6.2.2.2 Density

Density is simply the number of individual plants or stems within the reference area (Figure 6.2.2.2). Since this parameter requires that individual plants be discerned, density is best used for shrubs and trees; density can be almost impossible to measure for grasses.

6.2.2.3 Species Richness

Species richness is the number of different species within the reference area (Figure 6.2.2.3). This parameter requires that the individual be able to distinguish species from each other. The researcher need only count the number of species within the sample frame. If the density and/or cover data are tabulated by species, then this information for the plot will already be known.

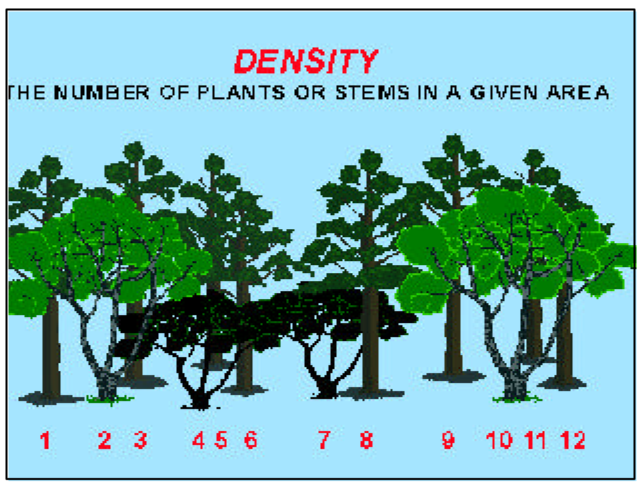

Figure 6.2.2.2: Definition of density. Within this one-acre plot, there is a density of 12 plants. If the data are tabulated by species, the data will result in a density of each species and a total density of the plot.

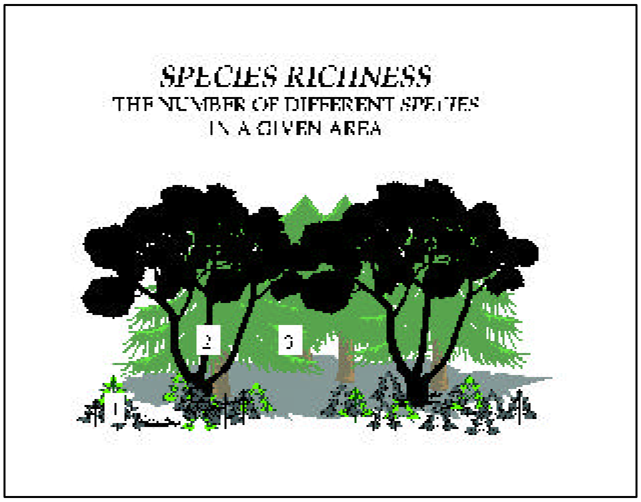

Figure 6.2.2.3: Definition of species richness.

6.2.2.4 Plant Growth

Plant growth measurements are not required under Article 9 of the SMGB regulations; however, plant growth data can be very helpful during the first few years of a project or on test plots where containers or cuttings are installed (Section 6.5 on test plots). Various types of growth measurements have been used in both forestry and plant ecology. Plant volume, as described herein, is generally applicable to various growth forms and works well during early growth phases (Figure 6.2.2.4a). This is an intensive measurement where the researcher assumes that the plant is a cylinder. The height of the plant is measured and the crown of the plant is measured in two directions, with the average of these two measurements used to calculate the "radius." These data are then applied to the formula for a cylinder (height X π r^2).

Growth data, as with plant cover data, are useful for tracking trends, as depicted in Figure 6.2.2.4b.

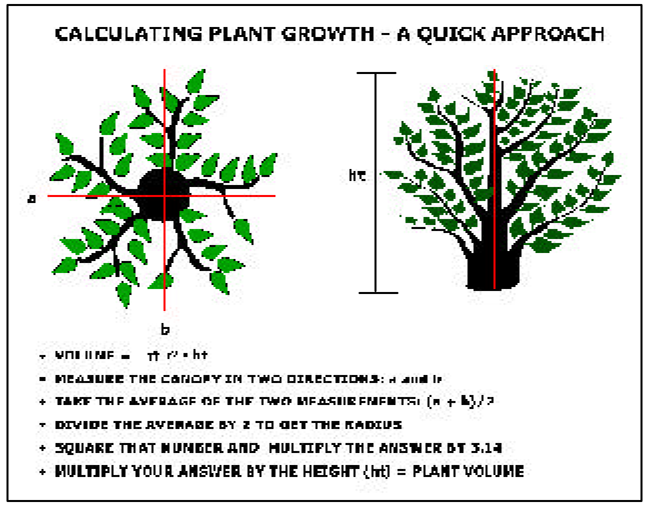

Figure 6.2.2.4a: Calculation of plant growth.

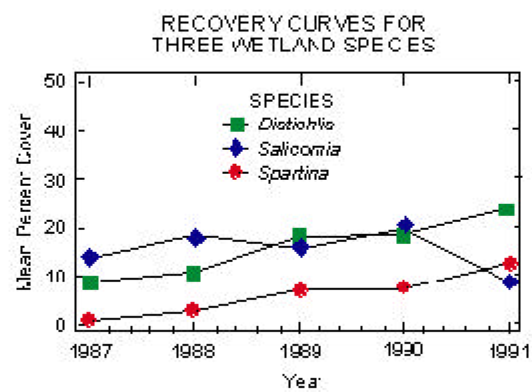

Figure 6.2.2.4b: Recovery curves for three wetland species (Newton 1991).

6.2.2.5 Plant Mortality/Survival

Plant mortality/survival monitoring simply determines whether or not a plant is alive (survival) or dead (mortality). An example of plant survival data is given in Table 6.2.2.5, and an example of plant mortality data is provided in Figure 6.2.2.5. Once again, this type of data is best taken on containers or cuttings and is most often used to determine the need for replacement plantings. A common standard for acceptable mortality is 20%, that is, an 80% survival rate. This standard may be difficult to obtain in harsh environments (low deserts) or on difficult substrates (serpentine or acidic mine spoils). A realistic standard should be developed for each site based on climate and substrate and on existing literature or research.

6.3 Erosion Control Monitoring

It can take from one to ten years for vegetation to become established on a rehabilitation site, depending on habitat and climate. During this time, the site is prone to wind and water erosion. If the substrate erodes, it decreases the ability of the site to support vegetation, thereby subverting the goals of the entire project. Obviously, it is important to

GENUS	# PLANTED	MEAN % SURVIVAL		% CHANGE
		1998	1999	
Ceanothus	88	40.59	20.69	-19.90
Cercocarpus	88	84.05	57.46	-26.59
Prunus	90	92.05	60.31	-31.74
Ribes	89	92.15	81.58	-10.57

Table 6.2.2.5: Woody species survival at Leviathan Mine, 1999 (Newton, unpublished data). In this table, survival for only one species was below the 80% level in 1998, but one year later, three species fell below that threshold. (Increased mortality was largely caused by rodent predation.)

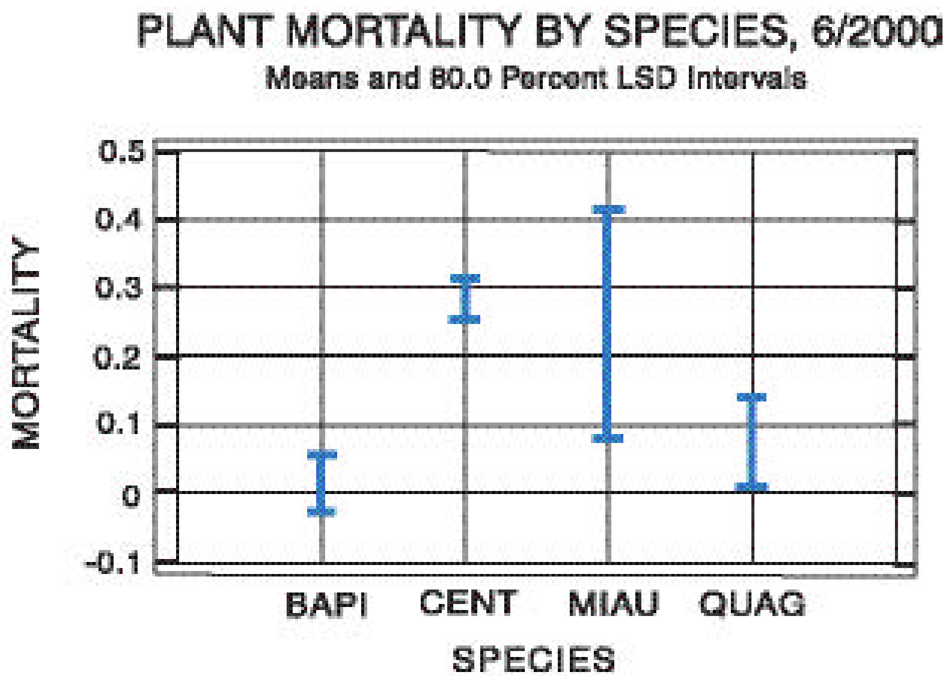

Figure 6.2.2.5: Plant mortality at Gambonini Mine June 2000 (Newton, unpublished data). When mortality is calculated with 80% least significant difference intervals (LSD), it is found that one of the species CENT (Ceanothus) is statistically above the mortality rate of 20% (i.e., survival is below 80%). While the mean of the mortality for MIAU (Mimulus) is above 20%, the large variability in the data (the 80% LSD) overlaps with the 20% or 0.2 threshold, and therefore, one cannot state that the mortality is significantly different from the threshold value.

monitor during the construction phase on a regular schedule to make sure the erosion control measures are being installed correctly. Once construction is finished, the performance of erosion control measures must be monitored to make sure they do their job.

Performance standards for erosion control usually address correct installation and maintenance, and are assessed during monitoring. An example of erosion control performance standards, beyond a simple statement of installation and maintenance is provided in the sidebar. A sample data collection sheet for monitoring of erosion control measures and a definition of the Classes referred to in the above example are included in Appendix B.

Monitoring of constructed erosion control measures should happen approximately one month before the onset of the rainy season and subsequently in conjunction with storm events. Many erosion control structures, such as a sediment basin or silt fence, require regular maintenance in order to function properly. The erosion control monitor should specifically check for structures that are in need of maintenance or re-construction, blocked structures (such as with debris), under-designed structures, undermined structures, unanticipated surface flows, rilling or gullying on finished slopes, and evidence of deposition in watercourses off-site. If problems are noted, they should immediately be repaired or additional measures added as suggested in the remedial measures. The monitor should then assure that remedial measures have been implemented.

6.4 Soils Monitoring

Soils monitoring is not that frequently implemented on a project until problems become evident. However, on mine sites where the soil presents some type of constraint to growth, usually the soil is sampled prior to final grading and planting, and if needed, amended at that time. Trying to amend soils after planting usually leads to destruction of the vegetation and is thus more costly.

If a substrate has required amending, or if physical constraints to growth occur (compaction), some type of soil monitoring program would be warranted. The soil monitoring program should target the expected constraints. That is, if compaction is suspected to be a growth limiting issue, then the program should include monitoring the site for compaction (Figure 6.4). If basic soil chemistry and soil nutrients are expected to be an issue, the monitoring program should follow the basic guidelines for soil sampling as outlined in Section 3 as modified below.

Soil monitoring uses a process of systematic collection of specific data that addresses a defined soil characteristic. It is not the open ended screening for deficiencies or toxicities as is done with general soil nutrient tests on unknown substrates. With monitoring, the generalities are fairly well described, and a specific characteristic of the soil is tracked and reanalyzed for the purpose of detecting change or maintenance of a target level. An adequate number of samples is needed in order to detect changes in the target characteristic. The initial surveys, if planned accordingly, can give adequate information on variability within the site. Typically, the statistically required numbers of samples exceed the ability (time or money) to resample the site. The level of confidence needs to be balanced against the cost of monitoring the site. For this reason, it may be cost effective to amend the site over-intensively

A SPECIFICATION FOR AN EROSION CONTROL PERFORMANCE STANDARD (DOC 1994)

Any area larger than 500 square feet that receives an average evaluation score of Class 2 or higher that persists for more than two consecutive years will be investigated. The need for remedial measures will be determined by the investigator. Areas receiving an average evaluation score of Class 3 or higher will receive treatment to correct the problem as set forth in the discussion on remedial measures. Any observable reason for failure will be noted and the appropriate remedial measure suggested as part of the annual monitoring report.

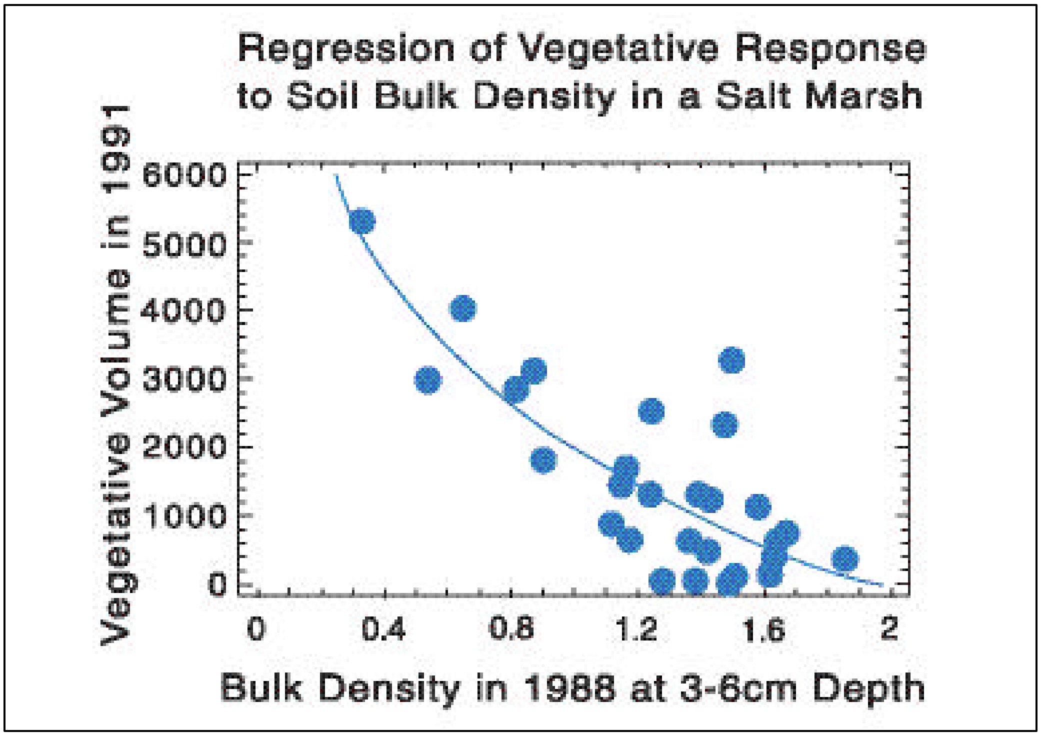

Figure 6.4: Response (regression) of vegetative volume to soil bulk density in a salt marsh (Newton, unpublished data). Soil units in gm/cm^3; r^2 = 64%, P < 0.00; logarithmic - X regression model.

initially, rather than cutting costs during site construction and then having to come back repeatedly to correct marginal conditions.

Options for response to deficiencies may be limited, since tillage and earthmoving are destructive to the revegetating community. Some fertilizers can be surface applied effectively after planting, if needed, although lime materials to correct pH are not effective as surface applications. An inexpensive, noninvasive soil monitoring method is to track plant response to the soil treatments. Some nutrient deficiencies or toxicities can be detected by observing plant leaf coloration and health. Some plant tissue analyses are useful for tracking soil conditions, although target levels are not well established for many wildlands plants. Target levels of critical characteristics can be inferred by comparison to nearby reference communities (disturbed but adequately revegetated, or native and undisturbed sites). Published literature or previous studies may provide target levels that are known to represent adequate soil nutrient levels by that particular nutrient extraction and analysis method, although, again, this information is usually not known for wildlands sites or plant species. Soil biological inventories are useful, but information about tolerance of organisms to harsh and extreme sites is not well known, so that this information may be only a general indicator. Finally, preliminary test plots are valuable because they can be more easily reworked when amendments are not adequate compared to amending the entire site. If a deficiency is suspected in established plots, uniform areas can be divided into a control (no application) and a test plot, in which soluble fertilizers containing only the desired nutrients are surface applied or shallow-tilled between plants.

6.5 Reporting

The rehabilitation plan should specifically state the frequency and duration of any reporting requirement. An example is provided in the sidebar.

The report of the monitoring data should be logically organized and clearly state the methodologies used for data collection and analysis. The results should be clearly and concisely stated with a comparison of the results versus the goals and performance standards. Much of this information can be presented in a tabular form. An example follows in Table 6.5.

The report should contain an analysis of the ability of the project to meet the performance standards with some explanation or discussion of the significance of the results. Conclusions should be drawn and stated succinctly with a section on recommendations. These recommendations may include the implementation of remedial measures, new techniques, or the change of performance standards.

6.6 Examples of Maintenance Activities and Remedial Measures

The following list of maintenance activities and remedial measures is not exhaustive, but it provides an idea of the sorts of problems that may arise and what can be done about them (Table 6.6a). To develop a list of appropriate maintenance activities and remedial measures, the project designers should evaluate each aspect of the project and decide how best to maintain that portion of the project (such as Table 6.5). As part of the monitoring program, the need for maintenance activities and remedial measures should be evaluated. Whether or not maintenance is performed can be left to the project manager or be pre-determined based on the threshold performance standards (Table 6.6b). If a problem is observed, quick measures must be taken to avoid a costly failure. If implementation of remedial measures leads to changed project goals, then performance standards and monitoring protocols may need to be adjusted.

6.6.1 EROSION CONTROL

During the establishment phase, vegetative cover is usually not adequate to prevent erosion. If erosion occurs, that failure may propagate across the site causing additional failures. Therefore, it is important to identify areas of erosion early and implement measures to prevent failures. Erosion control measures are outlined in Section 4, but maintenance erosion control measures may include addition of erosion control blankets, mulches, and replanting.

A SPECIFICATION FOR A REPORTING REQUIREMENT (CHAMBERS GROUP, INC. 1995)

Detailed maintenance and monitoring reports documenting the progress of the revegetation plantings will be submitted to the CDFG [California Department of Fish and Game] on the following basis:

- submitted monthly for Year 1,
- submitted quarterly for Years 2 and 3, and
- submitted annually for Years 4 and 5.

Performance and maintenance monitoring shall be performed for 5 years after planting, and reports shall be submitted to CDFG by January 31 of each year after planting starting in April 1996. The adequacy of all monitoring reports shall be subject to CDFG approval. Monitoring reports shall present an overview of the revegetation effort and specifically address monitoring methods, plant survival, percent cover, height of shrub species, and number of each species replaced. Photos from designated photo stations shall also be included.

6.6.2 WEED CONTROL

If an exotic plant species invades the site, it is often easiest and cheapest to eradicate the species early than to allow it time to take hold and set seed. First it must be determined if the invasive species is a threat to the goals of the project. Many projects experience a population explosion of weeds the first year or two after implementation. In some cases, these weeds naturally die out without causing any adverse effects. In other cases, they take over the site and crowd out the desired species and reduce species richness.

When evaluating the potential impacts of weeds on a site, decisions for eradication should be based

Table 6.5: Example of reporting table (from Newton 1991)

TASK	PROJECT OBJECTIVES	PERFORMANCE STANDARD	DATA YEAR 1	DATA YEAR 2	DATA YEAR 3	DATA YEAR 4	DATA YEAR 5
Rare species counts	1	numbers equal or exceed pre-project ORCAH=2,074	no data	2,561	7,229	5,968	7,282
		GRSTB=832	552	639	1,117	1,289	1,277
Rare species mapping	1	species re-occupy rehabilitated site	within site	within site	within and beyond site	within and beyond site	within and beyond site
Vegetation data (height, cover, species composition)	1, 2, 3	yr 1=20% cover by wetland species; yr 2=25%; yr 3=30%; yr 4=40%; yr 5=50%	27.6%	36.9%	48.9%	57.9%	56.8%
Vegetation type mapping	1, 2, 3	similar vegetation type (pickleweed/saltgrass) re-occupies rehabilitated site	pickleweed/ saltgrass	pickleweed/ saltgrass	pickleweed/ saltgrass	pickleweed/ saltgrass	saltgrass/ cordgrass
Bulk density sampling	1, 2, 3	soil bulk density (BD) on rehabilitated site not significantly different from undisturbed site (x=0.459g/cm3)	x=1.307 g/cm3; BD significantly higher	x=1.276 g/cm3; BD significantly higher	no data	no data	x=1.267g/cm3; BD significantly higher
Elevation measurements	1, 2, 3	elevations within range for desired vegetation type (7.5' to 8.3' MLLW)	8.07' MLLW	7.66' MLLW	no data	no data	7.72' MLLW
Area C vegetation sampling	4	decreased importance (cover) of weedy species	26.3%	18.5%	13.8%	5.8%	1.8%
		increase cover of desired species	23.3%	33.6%	44.2%	39.3%	45.2%
Public trespass analysis	5	no evidence of trespass	trespass evident	trespass evident	trespass evident	trespass evident	trespass evident

Objectives:
1) Restoration of rare plant populations directly affected by the project.
2) Restoration of wetland vegetation directly affected by the project.
3) Enhancement of degraded salt marsh habitats that will be disturbed by the project, i.e., decreased importance of weedy species.
4) Enhancement of degraded salt marsh habitats not disturbed by the project, i.e., decreased importance of weedy species.
5) Preservation of existing wetland values and processes outside of the project boundaries by restriction of public access.

GRSTB = *Grindelia stricta* var. *blakei* (G. *stricta* var. *stricta*.)
ORCAH = *Orthocarpus castillejoides* var.*humboldtiensis* (*Castilleja ambigua* ssp. *h*.)

Table 6.6a: Statement of maintenance activities and remedial actions

PROBLEM	MAINTENANCE ACTIVITIES AND REMEDIAL ACTION
Vehicular trespass	Signage, fencing, place large boulders at access points
Human trespass	Signage, fencing
Cattle trespass	Fencing; agreement with rancher to remove cattle from area; place salt licks and water source well away from rehabilitation site
Weeds abundant: composing greater than 10% of cover in any year	Use best available method for removal: hand removal, mowing, herbicide, cutting, etc.
Density of natives low: composing less than 50% of cover in any year	Reseed in fall with coastal scrub mix, rake into soil
Low oak germination: less than 20% of acorn hills with at least one plant in any year	Replant acorns in fall
Poor willow survival: less than 80% survival of poles in any year	Replace cuttings in December
Low shrub survival: less than 5 shrubs per 100 square meters in years one and two	Seed with manzanita and sagebrush in fall
Small portion unvegetated: area less than 200 square feet with less than 20% cover in years one and two	Till soil with rotary blade, follow contour of slope, and reseed with coastal scrub mix; cover with erosion control blanket
High mortality of containers: less than 80% survival in any year	Replant containers with like ecotypes; add fertilizer; decrease frequency of irrigation
High mortality of containers: less than 80% survival in any year with abundant insect damage	Determine species of insect and import predator; apply individual insect cages around containers
Rills forming	Till soil with rotary blade, follow contour of slope, and reseed with coastal scrub mix; cover with erosion control blanket
Erosion under waterbars	Rebuild waterbars and reinforce with sandbags
Undercutting of silt fence	Make sure silt build-up (i.e., lack of maintenance) has not caused failure. Rebuild silt fence, key into slope deeper and reinforce with rock; maintain
Blow-out of willow wattles	Determine cause of blow-out on slope above and fix; rebuild willow wattle and key into slope deeper; reinforce with additional willow poles driven through wattle

Table 6.6b: Remedial measures (from DOC 1994)

FEATURE	OBJECTIVES	MONITORING FREQUENCY	FINDINGS	ACTION
Wind Erosion	Soil stabilized, no nuisance dust from site.	Continuously during reclamation implementation; annually following reclamation.	Soil drifts found behind plants and rises; blowing dust.	Consider additional soil stabilization, i.e., straw mulching and revegetation.
Water Erosion	Soil stabilized, no evidence of rilling or gullying greater than a Class 3.	After first major storm event (>0.5 inch rain in a 24-hour period) following construction; once a year during annual monitoring of reclamation.	Rilling or gullying or erosion judged to be Class 3 or greater; or evidence of washouts or erosion in established drainage ways.	Repair area, consider additional stabilization (waterbars, berms, diversion channels, rock lining, erosion control blankets, or mulches).
Slope Stability	No evidence of slope failures.	Monitor continuously during site reshaping; and annually following implementation.	Slope failures, slumping.	Reconstruct slope, lessen angle of slope, and implement erosion control measures.
Sedimentation	Little accumulation of sediment in pit; pit maintains adequate capacity.	After first major storm event (>0.5 inch rain in a 24-your period) following reshaping; annually during reclamation.	Pit filling up; diminished capacity.	Clean out basin; analyze watershed for source of sediment; implement erosion control measures to correct problem.
Invasion by exotic plant species	No interference with establishment of native vegetation during reclamation.	Once per year, note areas of infestation of invasive exotics.	Infestation of exotics interfering with establishment of native vegetation.	Apply weed eradication measures: hand-pulling, hand-cutting, and possibly hand-applied herbicide.
Revegetation	Perennial cover at 15 percent, perennial density averages 4/100 sq. feet, and perennial species richness averages 2/100 sq. feet.	Annually following implementation.	<15 percent cover, and/or <4 perennials/100 square feet, and/or <2 perennial species/ 100 square feet; signs of herbivory that may significantly affect outcome.	Consider fertilizing and irrigating individual plants; consider reseeding; analyze soil for problems; analyze for pest problems (consider fencing individual plants).
Joshua Trees	24 surviving Joshua trees	Annually following transplantation	Tips of leaves yellowing, trees collapsing or tending to fall over, <24 survivingJoshua trees.	Consider fertilizing and continuing irrigation; consider tethering trees in place; consider replacing with trees from other projects on BLM property; analyze soil for problems; analyze for pest problems
Resoiling	Decompacted subsoil, topsoil respread with vegetative debris, waste fines and subsoil amended to provide adequate growth medium.	Monitor during implementation.	Compacted or nutrient poor growth medium.	Rip or disc site to alleviate compaction; have soil nutrient testing done and amend as suggested; respread additional fines, if available.

on whether the weed is interfering with the establishment of the desired species, and whether this weed is known to cause long-term problems. For example, annual exotic grasses of California's Central Valley germinate and begin an explosive growth phase before their native perennial counterparts, drying out and depleting the topsoil of nutrients and causing stress and death to newly planted perennials. Special measures, such as weed-stop mats or controlled burn, may be warranted.

Certain species are known to cause catastrophic failures by taking over rehabilitation sites. Table 6.6.2 provides a sampling of some of the more troublesome. The California Exotic Pest Plant Council maintains a website (*www.caleppc.org*) with information about invasive plants.

6.6.3 FERTILIZING

Nitrogen is the most common limiting nutrient on drastically disturbed soils because organic matter levels are low and because plant-available forms are easily leached from the soil. The amount of plant-available nitrogen that a soil can provide will be determined by the soil texture and the soil biota. If the growth medium was developed from coarse-textured mine wastes, it is likely that little nitrogen will be held in the soil. Until the nitrogen pools in the soil are replenished, a small amount of nitrogen may need to be added to the soil at the beginning of the growing season.

If plants are exhibiting stress due to nutrient deficiencies, fertilizer can be added to the site to prevent a high level of mortality. Classic signs of nutrient stress are listed in Table 6.6.3.

6.6.4 SUPPLEMENTAL WATERING

The goal on most rehabilitation sites is to provide a drought resistant vegetative cover, not one dependent on irrigation. However, due to yearly and seasonal variations, a little water to augment a dry spell may make the difference during the establishment phase. It is common to add supplemental water to a site, between rainfall events, during the first growing season. Supplemental water should be added infrequently (no more than once per week, usually once per month), and the watering should be thorough rather than superficial, so that the water soaks deeply into the ground.

6.6.5 REPLANTING

If the mortality is too high during the first season, it may be necessary to replant prior to the period of the highest rainfall to prevent erosion of the substrate.

6.6.6 CONTROL OF ANTHROPOGENIC EFFECTS AND HERBIVORY

Young plants are susceptible to anthropogenic effects (i.e., those caused by people) and herbivory. It is important to protect the rehabilitation site for at least the first growing season from pedestrian and vehicle access and from any type of grazing animal (cows to rabbits to grasshoppers). Frequent monitoring will determine if corrective measures are needed.

6.7 Test Plots (Field Trials)

Throughout this manual, test plots have been recommended. The purpose of test plots is to investigate on a small scale what treatments will work best when the rehabilitation is fully implemented. It is much more prudent to have demon-

> A SPECIFICATION FOR REPLANTING
>
> Survival of cuttings and containers shall meet the performance standards. Plants that have died or are not showing reasonable growth shall be replaced with an appropriate ecotype of the same species. The CDFG Representative shall be the final judge of the need to replace cuttings and containers. All seeded areas shall be guaranteed to have uniform coverage and to meet the performance standards. Any areas not achieving the standards shall be reseeded at no extra cost. Final acceptance for revegetation shall be given when the performance standards for year one are met as described in the monitoring plan.

Table 6.6.2: Exotic species that may need control

NAME	GEOGRAPHICAL DISTRIBUTION	ECOLOGICAL DISTRIBUTON	ERADICATON SPECIFICATIONS
Arundo donax Giant reed	Statewide	Riparian Areas Wetlands	Cut to base and immediately treat with Rodeo, or remove by hand. Re-treat after rhizomes resprout.
Tamarix spp. Salt cedar, tamarisk	Statewide	Riparian Areas Wetlands	Treat foliage with Arsenal; treat cut stumps with Rodeo or Garlon, remove 1-2 months after treatment.
Ailanthus altissima tree of heaven	Statewide	Riparian Areas Mesic Sites Disturbed Areas	Cut to base and immediately treat with Roundup or Garlon, or remove by hand. Re-treat after rhizomes resprout.
Ammophila arenaria European beachgrass	Statewide	Coastal Dunes	Treat with Roundup or Vapam, and/or grub out rhizomes; re-treat frequently.
Carpobrotus edulis iceplant	Statewide	Coastal Areas	Easily removed by hand-pulling; may also use Roundup. Re-treat.
Cortaderia spp. Pampass grass	Statewide	Coastal Areas to Foothills in a few locations	Cut to base and treat with Round-up; or cut topgrowth and grub out root crown.
Eucalytus globulus Blue gum	Statewide	Riparian Areas Mesic Sites	Treat cut stumps with Roundup, Rodeo, or Garlon; remove from site.
Centaurea solstitialis yellow star thistle	Statewide	Grasslands	Prescribed burn or grazing in June-July; or treat with Garlon or Transline.
Cytisus spp. an Genista monspessulana brooms	Statewide	All	Manual removal with weed wrench, with follow-up removal of seedlings. Or, treat with Roundup or Garlon, and burn; follow up with removal of seedlings.
Various annual grasses: *Bromus hordeaceus, Bromus tectorum, Bromus madritensis,Lolium multiflorum, Vulpia myros, Avena sp.*	Statewide	All	Pre-treat soils with pre-emergents. Protect desired vegetation with weed-mats. Controlled burn.

Table 6.6.3: Plant nutrient stress symptoms

SYMPTOM	POSSIBLE NUTRIENT STRESS
Stunted plant with leaves that are more yellowish than are normal for that species, especially when the top few leaves remain green while bottom leaves are yellowish	nitrogen deficiency
Stunted plant with purple or bronze leaves	phosphorus deficiency*
Stunted plant with leaf tip and marginal burn first on lower leaves and later advancing up the plant; the leaves may turn inward	potassium deficiency
Terminal leaf buds fail to develop fully and new leaves are incompletely formed or have irregular margin shapes	calcium deficiency
A yellowing of leaves (like nitrogen deficiency), but with the veins remaining green	magnesium or sulfur deficiency
A yellowing of leaves and stunted growth (like nitrogen deficiency), and the veins remain green (as with magnesium deficiency), but the yellowing first occurs on young leaves since iron is immobile with the plant	iron deficiency

** A newly installed plant may exhibit phosphorus deficiency signs because of the lack of root growth. Such a plant would be better treated with a mixture of N and P to promote root growth, rather than just P alone.*

strated that certain species and treatments will work on a site prior to the expense of full-scale implementation. In fact, the California Code of Regulations Section 3705(b) (which regulates mining) requires that test plots be implemented if the proposed revegetation plan has not been demonstrated to work in similar situations elsewhere. In addition, any test plot failures may help the practitioner decide upon further treatments in order to ensure success.

It may take five years, or more, to obtain reliable results from test plots; thus, a large amount of lead-time before implementation is necessary, and test plots need to be thoroughly thought out and correctly installed and monitored. This section provides a few guidelines.

6.7.1 PLACEMENT

Guidelines for placing test plots on a site should follow those included in Section 6.2.1 on stratifying a site. Separate areas for testing should be located in each of the different substrate types, vegetation types, and aspect/elevation types represented within the site where rehabilitation is to take place. On a large and complex site, the test areas and plots within those areas can become quite numerous. Nonetheless, it is very important that each test area is homogenous. For example, if one corner of the test area has significantly more acidic soils, the results from that test area may be skewed and careful work in plot design and construction may be wasted.

6.7.2 TREATMENTS

Typically, treatments are set-up by contrasts; that is, one type of treatment is tested against another. Common treatment contrasts include the use of different mulch treatments such as straw versus pine needles; the use of soil amendments such as lime and composts; the depth at which the soil amendments are mixed into the soil; the use of commercial mycorrhizal inoculum versus site-collected inoculum; the use of cuttings versus containerized plants versus seeds. The potential comparisons are nearly endless; time and money are usually the limiting factors.

The contrasts being tested can be added on top of other contrasts. For example, it may be desirable to test whether a mycorrhizae treatment works better without compost, with municipal sludge compost, or with steer manure compost.

Plant species can also be thought of as treatments. Test plots can be used to determine which plant species will do well on the site. Of course, the plants can also be the way in which the practitioner, through monitoring, determines whether the other treatments are working.

Control plots are an important part of the design of test areas. In other words, some plots in the test area should have no treatments in order to see what would happen on the site without intervention. However, the project manager may already know what control plots would produce. For example, if a mine site has been abandoned for a number of years and has nothing growing on it, the project manager might be able to assume that the control plots would show the same lack of results. Without such knowledge of the certain outcome of control plots, they should be part of the test design.

6.7.3 PLOT LAYOUT: RANDOM AND REPLICATED

Once a testing area has been chosen on the site and the treatments to be tested have been determined, it is easiest to install test plots within the area on a grid system, that is, either in a rectangular or square format (Photo 6.7.3), using a randomized block design. In other words, each treatment has to be randomly assigned to a plot and each plot within the test has to be replicated. Thus, in Figure 6.7.3, the various treatments (LOM, LM, etc.) have been randomly assigned to plots, and each treatment is replicated three times. Three replicates are often adequate, but more commonly four replicate plots are required. The more replicates, the easier to discern differences among treatments. If too few replicates are used, differences will be obscured.

Monitoring of plants is easiest if the plants are placed on a grid system within the plot. If plants are being tested within the plots, they must be randomly assigned to their positions within the plot. The number of plants of each species in a plot should be as close to equal as possible, and the locations of the plants within each plot must be kept track of for monitoring purposes. For seeded species, the seeds should also be randomly assigned positions in the plots.

Often it is important to include a “buffer” around each plot so that the treatments in different plots do not get mixed together near common edges (the “edge” effect). For example, if a control plot were located directly adjacent to a compost plot without any buffer, the plants in the control plot along the common edge might be able to reach over with their roots and feast on the compost. These buffers can also function as walkways to make monitoring easier and to keep trampling and compaction restricted to areas outside of the plots.

6.7.4 MONITORING OF TEST PLOTS

The guidelines for monitoring test plots are the

Photo 6.7.3: Plot design photo. Photo of design from same test area shown in Figure 6.7.3, at Sulphur Bank Mine

*

LOM					LM					LOS					LOD					L				
H	Q	H	Q	X	M	C	H	P	X	C	P	P	H	X	M	P	S	C	X	Q	P	Q	H	X
S	P	Q	P	C	S	M	C	S	C	M	Q	H	M	H	S	C	P	P	M	S	M	Q	S	P
S	C	M	P	Q	S	P	H	P	H	C	M	P	Q	S	H	H	S	Q	M	P	C	S	S	C
M	M	H	C	S	C	H	Q	P	M	C	S	S	Q	P	S	Q	M	P	H	M	H	C	H	Q
M	S	C	H	P	Q	M	Q	S	Q	Q	M	S	C	H	Q	H	C	Q	C	M	H	M	P	C
L					LOD					LOM					LM					LOS				
P	Q	M	P	X	M	C	P	H	X	H	M	C	Q	X	C	Q	Q	C	X	C	C	H	H	X
M	Q	S	M	H	P	C	H	P	Q	P	H	S	P	C	H	M	P	P	Q	P	Q	C	M	M
C	Q	S	H	C	Q	S	S	C	M	S	H	Q	Q	P	E	M	E	C	H	Q	E	H	M	Q
S	S	C	P	Q	S	M	Q	Q	S	C	M	S	M	P	H	H	E	P	E	E	P	C	Q	H
C	H	H	P	M	C	M	H	P	H	Q	P	H	C	S	Q	M	M	P	C	M	P	E	E	P
LM					LOS					LOD					L					LOM				
M	M	Q	H	X	Q	P	H	H	X	Q	C	E	H	X	P	Q	H	H	X	P	P	E	H	X
C	C	H	S	P	C	S	Q	M	P	Q	Q	H	E	Q	C	Q	P	E	M	E	M	Q	M	M
M	P	H	C	P	H	P	M	M	M	H	P	E	P	M	E	Q	M	E	P	C	P	Q	M	E
S	S	C	M	H	S	E	C	C	S	M	M	C	C	P	C	P	E	H	H	C	E	C	H	C
Q	S	Q	Q	P	H	P	S	Q	C	M	C	H	E	P	C	M	C	M	Q	Q	Q	P	H	H

TREATMENT

L	LIME
LOS	LIME/ORGANIC - SHALLOW
LOD	LIME/ORGANIC – DEEP
LM	LIME/MYCORRHIZAE
LOM	LIME/ORGANIC/MYCORRHIZAE

SPECIES

C	*Cercis occidentalis*
E	*Elymus glaucus*
H	*Heteromeles arbutifolia*
L	*Lotus scoparius*
M	*Mimulus aurantiacus*
P	*Pinus sabiniana*
Q	*Quercus berberidifolia*
S	*Sitanion hystrix (= Flymus elymoides)*
X	Root sample (*Quercus berberidifolia*)

← N

* Photo point

Figure 6.7.3: Plot design from a test area at Sulphur Bank Mine.

same as those laid out earlier for the monitoring of the entire rehabilitation project. Typically, test plots are monitored at least twice a year for the first year and once a year thereafter. Usually, a researcher wants to get reliable data from test plots as quickly as possible, but caution should be used in drawing conclusions from short-term results. Short-term differences in treatments may not produce long-term positive results, and short-term differences may even reverse in the long-term. Therefore, results derived from data less than five years old should be considered preliminary. The sample parameters discussed previously in Section 6 are all appropriate for test plots, with growth being the most useful for elucidating short-term growth responses to treatments by individual plants.

6.7.5 ANALYSES

Without the use of some basic statistical tests, it can be very difficult to get any reliable data from test plots. Many statistical references (e.g., Sokal and Rohlf 1981) and computer programs (e.g., Statgraphics by Statistical Graphics Corp. 1999) are available for use. The simplest method for testing between two treatments is a paired-comparison between means; however, this type of statistical test is limiting, especially if multiple treatments are to be tested. More complex designs lend themselves to a multivariate analysis of variance (MANOVA) or a nested analysis of variance (non-parametric alternatives also exist). Results from these types of analyses can check for difference among means for all levels of contrasts and can be displayed in tabular (Table 6.7.5) or graphic form (Figure 6.7.5).

6.7.6 NON-INTERFERENCE WITH TEST PLOTS

Anything done to the test plots outside of the experimental design may invalidate the results. For example, if the person doing the monitoring of the test plots yields to temptation and decides to hand weed a plot in order to help the desired plants grow better, such action may render that plot, and perhaps the entire test area, worthless. All plots used for comparison would have to be hand weeded as well to make the comparison valid. If the treatment were selected for full-scale implementation, then the entire project would need to be hand weeded to obtain results similar to the test plots. Such a large-scale maintenance program may be impractical. The point of the test plots is to test particular factors. The practitioner must stand back once the test plots are installed and allow those factors to operate.

This caution applies only to ad hoc activities. If certain maintenance activities are planned for the site, it might be worthwhile to test for the effects of the maintenance measures. Likewise, if the practitioner expects to use certain remedial measures, those may also be tested for in the plots.

Leviathan Mine — MANOVA — Effect of Soil Treatment, Duff Treatment, and Species on Vegetation Volume. (Type III Sums of Squares)

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A: SOILTREAT	6.87659×10^6	2	3.43829×10^6	3.07	0.0729
B: DUFF	465193.0	1	465193.0	0.41	0.5281
C: SPECIES	2.17069×10^8	3	7.23565×10^7	64.52	0.0000
RESIDUAL	1.9064×10^7	17	1.12141×10^6		
TOTAL (CORRECTED)	2.43742×10^8	23			

All F-ratios are based on the residual mean square error.

Table 6.7.5: A sample MANOVA. This table shows that significant differences were found for soil treatment and species. (Output from statgraphics by Statistical Graphics Corp. 1999)

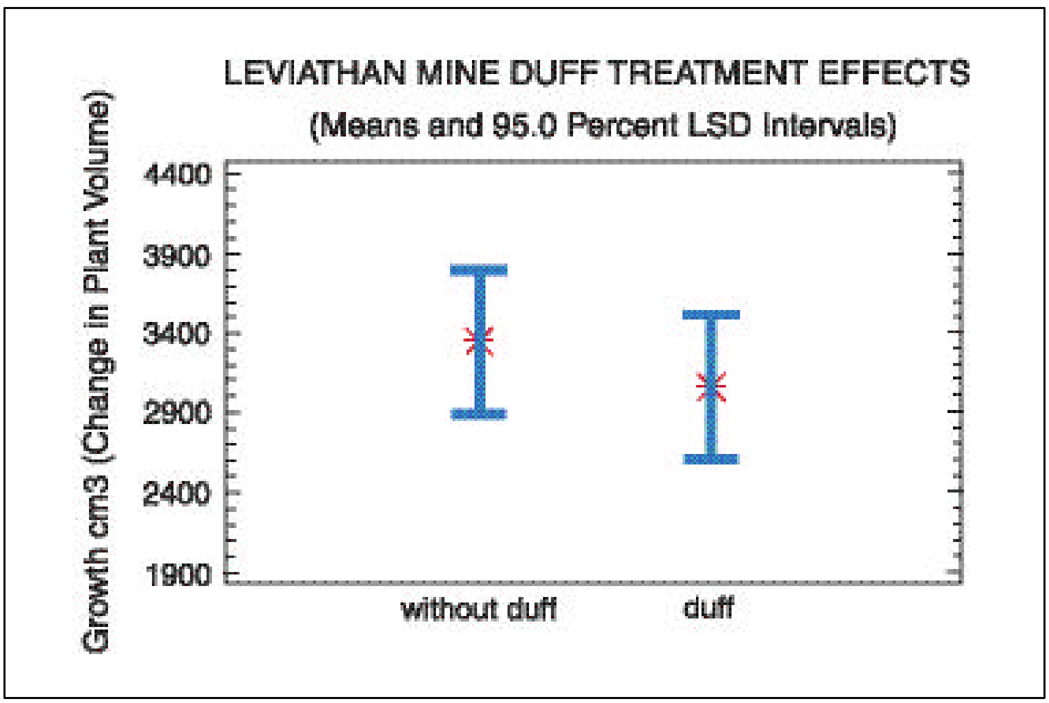

Figure 6.7.5: Graphic output from above. This test shows that vegetative volume was not significantly different when duff was added to a plot.

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APPENDIX A
SPECIES COMMONLY USED IN REHABILITATION BY BIOREGION *

* Refer to figure 5.1.1. for location of each bioregion (also know as geographic subregions).

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Anthoxanthum	*ordoratum*		sweet vernal grass	exotic	moist to wet	no seed treatment; seeds	disturbed sites; could be used for one year channel protection
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*occidentalis*	*Stipa o.*	needlegrass	native	dry	no seed treatment; seeds, containers	open dry sites, sagebrush scrub, coniferous forest, alpine
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Agrostis	*scabra*		ticklegrass	native	moist to wet	no seed treatment; seeds	roadsides, meadows, forests; could be used for multi-year channel protection; robust invader
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Alopecurus	*geniculatus*		water foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Calamagrostis	*foliosa*		leafy reedgrass	native	moist	no seed treatment; seeds, containers	bunchgrass; bluffs, cliffs, coastal scrub, forest
Calamagrostis	*nutkaensis*		Pacific reedgrass	native	moist to wet	no seed treatment; seeds, containers	bunchgrass; wet areas, beaches, dunes, coastal woodland
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Deschampsia	*caespitosa ssp. caespitosa*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, containers	meadows, streambanks, coastal marsh, forests, alpine; densely-tufted bunchgrass, excellent stabilizer; can withstand summer drought if saturated in spring
Deschampsia	*caespitosa ssp. holciformis*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	coastal marshes and meadows; clump forming, excellent stabilizer, tolerates saline water and saline soil
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*californicus*	*Hystrix c.*	bottlebrush grass	native	moist	no seed treatment; seeds, containers	coniferous forest
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Elymus	*trachycaulus ssp. trachycaulus*	*Agropyron subsecundus*	big squirreltail	native	dry to moist	no seed treatment; seeds, containers	dry to moist, open areas, forest, woodland
Elytrigia	*intermedia*	*Agropyron i.*	intermediate wheatgrass	exotic	dry to moist	no seed treatment; seeds	open areas, slopes; highly invasive, used for forage and erosion control
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives
Festuca	*californica*		California fescue	native	moist	no seed treatment; seeds, container	open forest, chaparral
Festuca	*idahoensis*		Idaho fescue	native	dry to moist	no seed treatment; seeds, containers	dry open or shady places
Festuca	*occidentalis*		western fescue	native	moist	no seed treatment; seeds, container	open pine/oak woodland, redwood forest
Festuca	*rubra*		red fescue	native	dry	no seed treatment; seeds, containers	varieties available (beware of less adaptive non-natives); sand dunes, grassland, subalpine forest; loosely tufted groundcover

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Festuca	*trachyphylla*		hard fescue	exotic	mesic	no seed treatment; seeds	open places, slopes; invasive
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Leymus	*mollis ssp. mollis*	*Elymus m.*	dunegrass	native	moist	seeds--low viability; containers, plugs	sandy beaches; requires good drainage; clump-forming, good stabilizer
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Melica	*californica*		California melic	native	dry	no seed treatment; seeds or containers	with short rhizomes, requires good drainage and full sun; tolerates serpentine
Melica	*torreyana*		Torrey's melic	native	dry	no seed treatment; seeds or containers	chaparral, coniferous forest; part shade
Nassella	*cernua*	*Stipa c.*	nodding needlegrass	native	dry	no seed treatment; seed, containers	bunchgrass; dry slopes in chaparral, grassland, and juniper woodland; best on well-drained sandy loam, but tolerates rocky soil; full sun to part shade; does well on poor soils; good stabilizer
Nassella	*lepida*	*Stipa l.*	foothill needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; dry slopes, chaparral, open woods; full sun to part shade; good bank stabilizer
Nassella	*pulchra*	*Stipa p.*	purple needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; adapted to clay soils, tolerant of summer drought and heat, tolerant of serpentine, tolerant of poor soils
Phalaris	*californica*		canary grass	native	moist	no seed treatment; seeds	moist areas in meadows and woodlands
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Pseudoroegneria	*spicata ssp. spicata*	*Agropyron s.*	bluebunch wheatgrass	native	dry	no seed treatment; seeds	sagebrush steppe, open woodland; requires good drainage and full sun

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Lasthenia	*glabrata*		goldfields	native	wet		saline places, vernal pools; requires full sun
Layia	*platyglossa*		tidy-tips	native	dry to moist		many habitats; requires full sun
Linanthus	*grandiflorus*		large-flowered linanthus	native	dry	seeds	generally in sandy soil on open, grassy flats; requires full sun and good drainage
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil; nitrogen-fixer
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer; nitrogen-fixer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
herb, perennial							
Abronia	*latifolia*		yellow sand verbena	native	dry to moist	no seed treatment; seeded	coastal sand dunes and coastal scrub
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds or container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Anaphalis	*margaritacea*		pearly everlasting	native	moist	no seed treatment; seeds	woods, roadsides, disturbance

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Argemone	*munita*		prickly poppy	native	dry	no seed treatment; seeds	open areas, disturbance
Armeria	*maritima ssp. californica*		sea thrift	native	moist	no seed treatment; seeds and containers	coastal dune, sand, exposed grasslands
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds and containers	open to shady places in drainages
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Artemisia	*suksdorfii*		coastal mugwort	native	moist to wet	no seed treatment; seeds and containers	coastal drainages, roadsides
Aster	*chilensis*		Pacific aster	native	moist to wet	no seed treatment; seeds, containers	grasslands, salt marshes, disturbed places
Calystegia	*soldanella*		beach morning-glory	native	dry to moist	seed requires treatment; seeds, containers	rhizomatous; sandy seashores, coastal strand
Camassia	*quamash ssp. quamash*		camas	native	wet	seed requires treatment; containers	damp forests, wet meadows, streamsides
Camissonia	*cheiranthifolia*		beach evening primrose	native	dry to moist	no seed treatment; seed	sandy slopes, flats, coastal dunes
Carex	*barbarae*		Santa Barbara sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; seasonally wet places; invasive
Carex	*nebrascensis*		Nebraska sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; meadows and swamps
Carex	*nudata*		sedge	native	wet	no seed treatment; seeds, cuttings, containers	clumped, not rhizomatous; grass-like; streambeds
Carex	*obnupta*		slough sedge	native	moist to wet	no seed treatment; cuttings, containers	rhizomatous; grass-like; tolerates some salinity
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection
Carex	*tumulicola*		Berkeley sedge	native	moist	no seed treatment; seeds, cuttings, containers	grass-like and rhizomatous; meadows, open woodlands
Eleocharis	*macrostachya*		spike rush	native	wet	seeds/plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Epilobium	*angustifolium ssp. circumvagum*		fireweed	native	dry to moist	no seed treatment; seeds, containers	open places, roadsides; can be invasive, especially after fire
Erigeron	*glaucus*		seaside daisy	native	dry	no seed treatment; low viability, seeds, containers	coastal bluffs, dunes, beaches; requires good drainage; low seed viability
Fragaria	*chiloensis*		beach strawberry	native	moist	no seed treatment; containers, sprigs	beaches, grassland
Fragaria	*vesca*		woodland strawberry	native	moist	no seed treatment; containers	partial shade in forests

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Heuchera	*micrantha*		alumroot	native	moist to wet	no seed treatment; rooted stem cuttings, containers	moist rocky banks and cliffs; good ground cover
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus .	*patens*		spreading rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; densely clumping, marsh places
Lathyrus	*littoralis*		beach pea	native	dry to moist	seed requires treatment; seeds, containers	open, coastal dune areas; sandy substrates
Linnea	*borealis var. longiflora*		twinflower	native	moist	stolon divisions; containers	moist shady places in coniferous forest; requires shade and good drainage; groundcover
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lotus	*corniculatus*		bird's-foot trefoil	exotic	moist	fresh seeds--no treatment, stored seeds-treatment; seed	Introduced exotic; requires good drainage and is a good stabilizer; tolerates shade and acidic substrates, nitrogen-fixer
Lotus	*junceus*		lotus	native	dry	no seed treatment; seeds	coastal strand and chaparral, sometimes on serpentine; requires good drainage and full sun, nitrogen-fixer
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Lupinus	*andersonii*		Anderson's lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	dry slopes, often under pines, nitrogen-fixer
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Monardella	*odoratissima*		coyote mint	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	gravelly flats and dry slopes in montane forest and sagebrush scrub
Monardella	*villosa*		coyote mint	native	dry	no seed treatment; vegetatively from rooted side shoots; seeds, containers	dry, rocky or gravelly places in oak woodland, chaparral, and montane forest; full sun to part shade
Oxalis	*oregana*		redwood sorrel	native	moist	no seed treatment; rhizome divisions; containers	moist conifer forests; shade; good groundcover
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase viability); seed, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Penstemon	*speciosus*		showy penstemon	native	dry	seed requires treatment; seed, containers	open sagebrush scrub to subalpine forest; requires good drainage and full sun
Potentilla	*anserina ssp. pacifica*		Pacific silverweed	native	wet	seed requires treatment; division of stolons; seed, containers	wetlands; good stabilizer; tolerates somewhat alkaline soils
Potentilla	*gracillis*		slender cinquefoil	native	moist	no seed treatment; seeds	mostly moist places in meadows and open forests; full sun
Salicornia	*virginica*		pickleweed	native	moist to wet	no seed treatment; containers	salt marshes near high tide elevations, alkaline flats; good stabilizer
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Sedum	*spathulifolium*		creeping stonecrop	native	dry to moist	containers	outcrops in forest communities, often in shade; requires good drainage
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds or containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Sisyrinchium	*californicum*		yellow-eyed grass	native	moist to wet	no seed treatment; rhizome divisions; seeds or containers	grass-like; moist, sunny places near coast
Tanacetum	*camphoratum*	*T. douglasii*	dune tansy	native	dry	no seed treatment, germination may be poor; seeds or divisions	good coastal groundcover, sandy soils, full sun
Trifolium	*macrocephalum*		bighead clover	native	dry	seed requires treatment; seeds, containers	dry, often rocky soils, often amongst sagebrush or under yellow pine; requires good drainage and full sun; associates with N-fixing bacteria
Trillium	*ovatum*		trillium	native	moist	seed requires treatment; seed, containers	redwood and mixed evergreen forest, shade and good drainage required, avoid heavy clay or sandy soils
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
Wyethia	*angustifolia*		narrowleaf mules ears	native	dry	seed treatment not necessary, but may help; seeds, containers	requires full sun and good drainage, grassland
Xerophyllum	*tenax*		beargrass	native	dry to moist	seed requires treatment; rhizome cuttings; containers	requires good drainage, often on steep slopes with shallow soils, tolerates serpentine and gabbro soils, prefers sun, moderately shade-tolerant
shrub, subshrub							

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Ambrosia	*chamissonis*		beach-bur	native	dry to moist	no seed treatment; seeds	sandy soils of beaches and dunes
Arctostaphylos	*nevadensis*		pinemat manzanita	native	dry	seed requires treatment; containers	rocky soils, coniferous forest
Artemisia	*pycnocephala*		coastal sagewort	native	dry to moist	no seed treatment; seeds and containers	coastal dune, rocky or sandy soils
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral
Berberis	*nervosa*		barberry	native	moist	seed requires treatment; containers	coniferous forest
Ceanothus	*cordulatus*		mountain whitethorn	native	dry	seed requires treatment; containers	can be prostate; rocky ridges, open pine forests; requires good drainage, nitrogen-fixer
Ceanothus	*gloriosus var. gloriosus*		Pt. Reyes ceanothus	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; some varieties tolerate very sandy soils; seeds require dormancy treatment; prostrate; coastal bluffs, c, nitrogen-fixer; closed-cone-pine forest
Ceanothus	*griseus*		Carmel ceanothus	native	dry	seed requires treatment; seeds, containers	requires good drainage; tolerates full sun; prostrate--provides good groundcover; seeds require dormancy treatment; coastal scrub, closed-cone-pine forest, nitrogen-fixer
Ceanothus	*prostratus*		mahala mat	native	dry	seed requires treatment; containers	prostrate and mat-forming--good ground cover; open flats, coniferous forest; highly variable; requires good drainage, nitrogen-fixer
Ceanothus	*thrysiflorus*		blue blossom	native	dry	seed requires treatment; seeds, containers	requires good drainage; prostrate to erect; provides good groundcover and good stabilization; can tolerate some shade on south-facing slopes; wooded slopes and canyons; nitrogen-fixer
Epilobium	*canum*	*Zauschneria californica*	California fuchsia	native	dry	no seed treatment; seeds, containers	dry slopes and ridges; different varieties; requires full sun and good drainage; spreads from underground stems; provides showy groundcover and is a good stabilizer
Ericameria	*ericoides*	*Haplopappus ericoides*	coast goldenbush	native	dry	no seed treatment; seeds, containers	dunes and inland sandy soils; requires full sun and good drainage
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Eriogonum	*latifolium*		Coast buckwheat	native	dry to moist	no seed treatment; seeds, containers	requires full sun and good drainage; does best near the coast in very sandy soils
Eriogonum	*umbellatum*		sulfur-flowered buckwheat	native	dry	no seed treatment (treatment increases viability); seeds, containers	many varieties; dry open, often rocky places; some varieties tolerate serpentine
Eriophyllum	*conferiflorum*		golden yarrow	native	dry	no seed treatment (treatment increases viability); seeds, containers	many dry habitats
Eriophyllum	*lanatum*		woolly sunflower	native	dry to moist	no seed treatment; seeds, containers	many varieties in many habitats
Gutierrezia	*californica*		snakeweed	native	dry to moist	no seed treatment; containers	grasslands, slopes, outcrops, sometimes on serpentine
Keckiella	*corymbosa*		redwood bush penstemon	native	dry	no seed treatment; seeds, containers	rocky slopes in coniferous or hardwood forests; requires good drainage
Lepechinia	*calycina*		pitcher sage	native	dry	seed requires treatment; seeds, containers	rocky slopes, chaparral, woodland; requires good drainage
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Lessingia	*filaginifolia*	*Corethrogyne f.*	California-aster	native	moist		highly variable; coastal scrub, oak woodlands, grasslands
Lonicera	*hispidula var. vacillans*		Californica honeysuckle	native	moist	seed requires treatment; cuttings; containers	along streams and on slopes in coniferous and foothill woodlands; requires shade; good ground cover; tolerates clay soils
Lupinus	*variicolor*		varicolored lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	meadows, coastal terraces and beaches, nitrogen-fixer
Mimulus	*aurantiacus*	*Diplacus, Mimulus longiflorus*	sticky monkeyflower	native	dry	no seed treatment; seeds or containers	consists of many different varieties; requires good drainage; requires full sun near coast, yet tolerates some shade inland
Penstemon	*newberryi*		mountain pride	native	dry	seed requires treatment; containers	granite rock outcrops, talus; requires good drainage
Polygonum	*paronychia*		dune knotweed	native	dry	seed requires treatment; containers	coastal dunes and scrub; requires good drainage; full sun-part shade; good groundcover
Salvia	*sonomensis*		creeping sage	native	dry	seed requires treatment; divisions; cuttings; containers	chaparral, oak woodland, and yellow pine forest; prostrate, mat-forming; requires good drainage, full sun, dry sites; provides a good groundcover; fire resistant if mowed and lightly irrigated; tolerates clay and serpentine soils
Symphoricarpos	*mollis*		creeping snowberry	native	moist	seed requires treatment, cuttings or divisions; containers	dry, part-shady conditions in woods; good slope cover
Whipplea	*modesta*		yerba de selva	native	dry to moist	no seed treatment; containers	well-drained slopes in coniferous forest; prefers shade; forms a trailing, deciduous groundcover

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
shrub, vine							
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
Vitis	*californica*		California wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; sprawling, climbing growth habit; tolerates most soil textures; sun or access to sun; fast-grower, forms groundcover if no support
shrub							
Acer	*circinatum*		vine maple	native	moist to wet	seed requires treatment; container	shaded streambanks
Adenostoma	*fasciculatum*		chamise	native	dry	fresh seeds require no treatment; seeds, containers	dry slopes, chaparral
Aesculus	*californicus*		buckeye	native	dry to moist	no seed treatment; seeds and containers	dry slopes, canyons, near streams
Amelanchier	*alnifolia*		western serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open shrublands and coniferous forest
Amelanchier	*utahensis*		Utah serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open slopes, shrubland, pinyon/juniper woodland, coniferous forest
Arctostaphylos	*manzanita*		common manzanita	native	dry	seed requires treatment; containers	rocky soils, chaparral, woodland, forest
Arctostaphylos	*patula*		greenleaf manzanita	native	dry	seed requires treatment; seeds, containers	shrublands, open coniferous forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment
Baccharis	*pilularis*	*B. p. var. consanguinea*	coyote bush	native	dry to moist	no seed treatment; seed, containers	coastal bluffs to woodlands, sometimes on serpentine; requires good drainage; provides good groundcover and good stabilization; some varieties are serpentine tolerant
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Calycanthus	*occidentalis*		spicebush	native	moist	seed requires treatment; containers	moist, shady places along streams
Ceanothus	*cuneatus*		buckbrush	native	dry	seed requires treatment; containers	many varieties, variable, prostrate to subshrub to shrub; some serpentine tolerance; requires good drainage; widespread, nitrogen-fixer
Ceanothus	*integerrimus*		deer brush	native	dry	seed requires treatment; containers	dry slopes, ridges; highly variable; disturbed roadsides, nitrogen-fixer
Ceanothus	*velutinus var. velutinus*		tobacco bush	native	dry	seed requires treatment; containers	open, wooded slopes, disturbed areas; nitrogen-fixer

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Cephalanthus	*occidentalis var. californicus*		buttonwillow	native	moist to wet	no seed treatment; cuttings, containers	riparian, lake, streamedges, drainages; can withstand reservoir drawdown
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; seeds require dormancy treatment; nitrogen-fixer; occurs in many habitats
Cercocarpus	*betuloides*		mountain mahogany	native	dry	no seed treatment; containers	chaparral, pine/oak woodland, coniferous forest; many varieties
Cercocarpus	*ledifolius*		curl-leaf mountain ma+D51hogany	native	dry	seed requires treatment; containers	deep soils, rocky slopes; requires good drainage; pinyon/juniper, sagebrush scrub, open pine forest
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related
Chrysothamnus	*viscidiflorus*		yellow rabbitbrush	native	dry	no seed treatment; seeds, containers	many subspecies; sagebrush, pinyon/juniper woodland
Cornus	*sericea ssp. sericea*	*Cornus stolonifera*	red osier dogwood	native	moist	seed requires treatment; stem cuttings, containers	many moist habitats; rooting stems
Corylus	*cornuta var. californica*		California hazelnut	native	moist	seed requires treatment; containers	riparian; shady places in many habitats
Dendromecon	*rigida*		bush poppy	native	dry	seed requires treatment; rooted stem cuttings, containers	dry slopes and washes, recent burns; requires good drainage
Eriodictyon	*californicum*		yerba santa	native	dry to moist	seed requires treatment; seeds, containers	open areas, slopes, fields, roadsides, woodland, chaparral; invasive after disturbance; requires good drainage
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Garrya	*elliptica*		silktassel	native	dry to moist	seed requires treatment; containers	seacliffs, sand dunes, chaparral, foothill-pine woodland
Garrya	*fremontii*		mountain silktassel	native	dry to moist	seed requires treatment; containers	chaparral, foothill woodland, montane forest
Gaultheria	*shallon*		salal	native	moist	no seed treatment; containers	moist forest margins; tolerates acid soil; good ground cover
Heteromeles	*arbutifolia*		toyon	native	dry to moist	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	chaparral, oak woodland, mixed-evergreen forest; requires full sun and good drainage
Holodiscus	*discolor*		oceanspray	native	moist	seed requires treatment; containers	moist woodland edges, rocky slopes
Holodiscus	*microphyllus*		rock spiraea	native	dry to moist	seed requires treatment; containers	rocky places, outcrops; a few varieties
Lonicera	*involucrata*		twinberry	native	moist to wet	seed requires treatment; cuttings; containers	moist places, such as riparian areas; sun to part shade

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lupinus	*arboreus*		yellow bush lupine	native	moist	fresh seeds--no treatment, stored seeds-treatment; seeds	requires full sun and good drainage; tolerates sandy soils; is a good stabilizer; invasive exotic to Klamath Region, nitrogen-fixer
Oemleria	*cerasiformis*	*Osmoraonia c.*	oso berry	native	moist	seed requires treatment; plant divisions; containers	shaded coniferous forest and chaparral; may not do well on poor soils
Philadelphus	*lewisii*		mock orange	native	dry to moist	seed requires treatment; containers	variety of sites from rockslides and cliffs to along water courses; soils range from deep, rich alluvial loams to rocky or gravelly loams; full sun to part shade
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Potentilla	*fruticosa*		bush cinquefoil	native	moist to wet	no seed treatment (treatment increases viability); softwood cuttings; containers	meadows, rocks; fertile, moist, well-drained soil; full sun
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade
Prunus	*illicifolia*		hollyleaf cherry	native	dry	fresh seeds-no treatment, stored seeds-treatment; seeds, containers	slopes and canyons of shrubland and woodland; requires good drainage, sun to part shade; attracts beneficial insects
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Purshia	*tridentata*		antelope bitterbrush	native	dry	seed requires treatment; containers	dry Joshua tree or pinyon-juniper woodland; requires good drainage and full sun; tolerates rocky, but not saline, soils; nitrogen-fixer
Quercus	*berberidifolia*	*Q. dumosa misapplied*	scrub oak	native	dry to moist	seed requires treatment if stored; acorns, containers	dry slopes in chaparral; requires good drainage and full sun; some ecotypes acid-tolerant
Quercus	*vaccinifolia*		huckleberry oak	native	dry	seed requires treatment if stored; acorns, containers	steep slopes and ridges in coniferous forest and subalpine areas; tolerates rocky and serpentine soils
Rhamnus	*californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	requires good drainage, tolerates partial shade; riparian species in the south; subspecies occidentalis is serpentine tolerant
Rhamnus	*californica ssp. californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	hillsides and ravines in chaparral, woodland, forest, and coastal sage scrub; does not tolerate serpentine soils; requires good drainage; host to beneficial insects

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Rhamnus	*ilicifolia*	*R. crocea ssp. I.*	hollyleaf redberry	native	dry	fresh seeds require no treatment; containers	chaparral, montane forests, good on dry banks
Rhamnus	*tomentella ssp. tomentella*	*R. californica ssp. t.*	hoary coffeeberry	native	dry	fresh seeds require no treatment; containers	chaparral and woodlands; requires good drainage and sun
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Ribes	*aureum*		golden currant	native	moist	seed requires treatment; suckers or cuttings; containers	riparian areas and canyons; sun to part shade; fine- to coarse-textured loam soils
Ribes	*malvaceum*		chaparral currant	native	dry to moist	seed requires treatment; containers	dry hills of Coast Ranges; requires good drainage; sun on coast and part shade inland
Ribes	*sanguineum*		red flowering currant	native	moist	seed requires treatment; tip cuttings; containers	moist, shaded places in forests of Coast Ranges; requires good drainage
Ribes	*velutinum*		desert gooseberry	native	dry	seed requires treatment; containers	dry slopes and coarse soils in sagebrush steppe, juniper woodland, and pine forest
Rosa	*californica*		California wild rose	native	moist	seed requires treatment; containers	riparian; prefers shade in the interior, sun on coast or at high elevations
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rubus	*leucodermis*		blackcap raspberry	native	moist	seed requires treatment; cuttings, root divisions; containers	hillslopes, canyon flats, and steambanks in montane areas
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salix	*scouleriana*		Scouler's willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, forests; requires sun
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
Sambucus	*racemosa*		red elderberry	native	moist	seed requires treatment; stem cuttings, containers	moist places, especially riparian; coastal and montane varieties; important to wildlife
Spiraea	*douglasii*		western spirea	native	moist	seed requires treatment; containers	moist, open, sunny areas in coniferous forest, especially in riparian areas; requires good drainage

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Styrax	*officinalis var. redivivus*	*S. o. var. californica*	snowdrop bush	native	dry	seed requires treatment; containers	full sun to light shade; dry places in chaparral and woodland; tolerates drought, heat, and rocky soils
Vaccinium	*ovatum*		evergreen huckleberry	native	moist	no seed treatment, but may improve germination; cuttings, containers	edges and clearings in coniferous forest; cool, moist, partly shaded conditions; pH range 4-6; thrives on acidic soils
Vaccinium	*parvifolium*		red huckleberry	native	moist	no seed treatment, but may improve germination; cuttings, containers	moist, shaded woods
tree							
Abies	*concolor*		white fir	native	moist	seed requires treatment; tubelings, supercell	mixed conifer to lower red-fir forests
Abies	*grandis*		grand fir	native	moist	seed requires treatment; tubelings, supercell	redwood forests, and lower elevation douglas-fir and mixed evergreen forests
Acer	*macrophyllum*		big-leaf maple	native	moist to wet	seed requires treatment; container	riparian, streambanks, canyons
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands
Alnus	*rhombifloia*		white alder	native	moist	no seed treatment, but low viability; cuttings, containers	riparian; rivers and streams, nitrogen-fixer
Alnus	*rubra*	*A. oregona*	red alder	native	wet	no seed treatment, but low viability; cuttings, containers	riparian; invades disturbed streamsides, nitrogen-fixer
Arbutus	*menziesii*		madrone	native	dry to moist	seed requires treatment; container	coniferous and oak forests
Betula	*occidentalis*		water birch	native	wet	seed requires treatment; containers	riparian, streamsides
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Chrysolepis	*chrysophylla*		chinquapin	native	dry to moist	fresh seeds--no treatment; containers	coniferous forest, closed-cone-pine forest, chaparral; one variety shrubby
Cornus	*nuttallii*		mountain dogwood	native	moist	seed requires treatment; containers	various woodlands and forest; requires shade
Cupressus	*lawsoniana*	*Chamaecyparis l.*	Port Orford cedar	native	moist	no seed treatment; low seed viability, containers	coastal conifer, mixed-evergreen, yellow-pine forest; tolerates serpentine
Cupressus	*macrocarpa*		Monterey cypress	native	dry to moist	no seed treatment; low seed viability, containers	closed cone-pine-cypress forest; native to Monterey Penn., but widely planted in cultivation
Fraxinus	*dipetala*		California ash	native	moist	seed requires treatment; containers	riparian, canyons, slopes, chaparral, oak/pine woodland
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Juglans	*californica var. hindsii*		Hinds walnut	native	moist	seed requires treatment; containers	riparian, canyons, valleys

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lithocarpus	*densiflorus*		tanoak, tanbark oak	native	dry to moist	fresh seeds--no treatment; containers, supercells	requires good drainage and part shade; associates with conifers and other hardwoods
Myrica	*californica*		wax myrtle	native	moist	seed requires treatment; cuttings; containers	moist, rich soil in shade or sun; canyons and moist slopes in redwood and closed cone pine forests, coastal dunes and scrub
Picea	*sitchensis*		Sitka spruce	native	moist	no seed treatment (treatment may increase viability); containers	moist, deep, well-drained soils near mouths of coastal rivers; tallest spruce species
Pinus	*attenuata*		knobcone pine	native	dry	seed requires treatment; containers	barren, rocky soils (often serpentine) in closed-cone pine forest and chaparral; tolerates fire; requires good drainage and full sun
Pinus	*contorta*		lodgepole pine	native	moist	fresh seeds-no treatment, stored seeds-treatment; containers	coastal to subalpine forest; many soil types; tolerates fire
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*lambertiana*		sugar pine	native	moist	seed requires treatment; cuttings possible; containers	mixed conifer and mixed evergreen forests; moist, steep, north- and east-facing slopes to more mesic south-facing slopes; requires good drainage; world's tallest pine
Pinus	*ponderosa*		ponderosa pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; grows on many soil types
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Populus	*tremuloides*		quaking aspen	native	moist	no seed treatment; best from stem cuttings	higher elevation riparian, moist openings, and slopes in forests, woodlands, and sagebrush steppe; cultivars used for phytoremediation; requires full sun and good drainage; good stabilizer; does not tolerate long-term flooding
Pseudotsuga	*menziesii var. menziesii*		Douglas-fir	native	moist	seed requires treatment (no treatment may be satisfactory)	mixed evergreen and mixed conifer forests; sun to part shade
Quercus	*agrifolia*		coast live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	valleys and slopes in mixed evergreen forest and woodland; requires full sun and good drainage
Quercus	*chrysolepis*		canyon live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	canyons, shaded slopes, chaparral, mixed evergreen forest, woodland; full sun to part shade; tolerates wide range of soil types, including rocky substrates, heavy clay, and serpentine

Appendix A1	NORTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Quercus	*douglasii*		blue oak	native	dry	seed requires treatment if stored; acorns, containers	dry slopes in woodlands of interior foothills; requires full sun and good drainage
Quercus	*garryana*		Oregon oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes in woodland and mixed evergreen or conifer forest; tolerates poor soils; shrubby subspecies
Quercus	*kelloggii*		black oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes, valleys, woodland, coniferous forest; fire-related; requires good drainage, sun to part shade
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding
Quercus	*wislizenii*		interior live oak	native	dry	seed requires treatment if stored; acorns, containers	interior canyons, slopes, and valleys; requires full sun and good drainage
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Sequoia	*sempervirens*		coast redwood	native	moist	no seed treatment, germination rate averages 10%; cuttings; containers	coastal fog belt; wide spreading shallow root system; mulch heavily
Thuja	*plicata*		western red cedar	native	moist	no seed treatment, when treated results are variable; containers	coastal conifer forest; part shade desirable; does not compete well with other plants including shrubs, high soil moisture limits competition; tolerates many soil types
Torreya	*californica*		California nutmeg	native	moist	seed requires treatment; containers	shady canyons of forests and woodlands, best in high humidity areas with good drainage
Tsuga	*heterophylla*		western hemlock	native	moist	seed treatment recommended, cuttings; containers	good drainage required, thrives under coastal fog and precipitation most soil textures, does not tolerate serpentine
Umbellularia	*californica*		California bay	native	dry to moist	seed requires treatment; untreated fresh seed yields slow germination; containers	riparian canyons (tree); chaparral (shrub); shade to sun; loam, sandy loam, or clay soils, tolerates serpentine; releases terpenes that inhibit weeds

Appendix A2	CASCADE RANGE						
Genus	Species	Synonym	Common Name	Origin	Tolerance	Propagation	Comments
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*hymenoides*	*Oryzopsis hymenoides*	Indian ricegrass	native	dry	fresh seeds require no treatment; seeds and containers	dry, sandy soil, desert shrub, sagebrsuh scrub, pinyon/juniper
Achnatherum	*occidentalis*	*Stipa o.*	needlegrass	native	dry	no seed treatment; seeds, containers	open dry sites, sagebrush scrub, coniferous forest, alpine
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Alopecurus	*geniculatus*		water foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Deschampsia	*caespitosa ssp. caespitosa*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, containers	meadows, streambanks, coastal marsh, forests, alpine; densely-tufted bunchgrass, excellent stabilizer; can withstand summer drought if saturated in spring
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Elymus	*trachycaulus ssp. trachycaulus*	*Agropyron subsecundus*	big squirreltail	native	dry to moist	no seed treatment; seeds, containers	dry to moist, open areas, forest, woodland
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives
Festuca	*californica*		California fescue	native	moist	no seed treatment; seeds, container	open forest, chaparral
Festuca	*idahoensis*		Idaho fescue	native	dry to moist	no seed treatment; seeds, containers	dry open or shady places
Festuca	*occidentalis*		western fescue	native	moist	no seed treatment; seeds, container	open pine/oak woodland, redwood forest
Festuca	*rubra*		red fescue	native	dry	no seed treatment; seeds, containers	varieties available (beware of less adaptive non-natives); sand dunes, grassland, subalpine forest; loosely tufted groundcover
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Muhlenbergia	*rigens*		deergrass	native	moist	no seed treatment; vegetatively by plant divisions; containers	along streams, meadow edges, hillside seeps, ditches, and roads; dry, damp, or moist conditions; full sun to part shade; withstands short duration flooding; tolerates flooding; forms dense clumps
Nassella	*lepida*	*Stipa l.*	foothill needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; dry slopes, chaparral, open woods; full sun to part shade; good bank stabilizer
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Pseudoroegneria	*spicata ssp. spicata*	*Agropyron s.*	bluebunch wheatgrass	native	dry	no seed treatment; seeds	sagebrush steppe, open woodland; requires good drainage and full sun
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
herb, annual							
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil; nitrogen-fixer
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer; nitrogen-fixer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
herb, perennial							
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds or container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Anaphalis	*margaritacea*		pearly everlasting	native	moist	no seed treatment; seeds	woods, roadsides, disturbance
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds and containers	open to shady places in drainages
Camassia	*quamash ssp. quamash*		camas	native	wet	seed requires treatment; containers	damp forests, wet meadows, streamsides
Carex	*barbarae*		Santa Barbara sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; seasonally wet places; invasive
Carex	*nebrascensis*		Nebraska sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; meadows and swamps
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection
Castilleja	*linariifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	dry plains, rocky slopes, sagebrush shrubland, pinyon/juniper woodland
Eleocharis	*macrostachya*		spike rush	native	wet	seeds, plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Epilobium	*angustifolium ssp. circumvagum*		fireweed	native	dry to moist	no seed treatment; seeds, containers	open places, roadsides; can be invasive, especially after fire
Fragaria	*vesca*		woodland strawberry	native	moist	no seed treatment; containers	partial shade in forests
Heuchera	*micrantha*		alumroot	native	moist to wet	no seed treatment; rooted stem cuttings, containers	moist rocky banks and cliffs; good ground cover
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus .	*patens*		spreading rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; densely clumping, marsh places
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Linnea	*borealis var. longiflora*		twinflower	native	moist	stolon divisions; containers	moist shady places in coniferous forest; requires shade and good drainage; groundcover
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lupinus	*argenteus*		mountain lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	montane forest and sagebrush scrub, nitrogen-fixer
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Monardella	*odoratissima*		coyote mint	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	gravelly flats and dry slopes in montane forest and sagebrush scrub
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase viability); seeds, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils
Penstemon	*speciosus*		showy penstemon	native	dry	seed requires treatment; seed, containers	open sagebrush scrub to subalpine forest; requires good drainage and full sun

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Potentilla	*gracillis*		slender cinquefoil	native	moist	no seed treatment; seeds	mostly moist places in meadows and open forests; full sun
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Sedum	*spathulifolium*		creeping stonecrop	native	dry to moist	containers	outcrops in forest communities, often in shade; requires good drainage
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds or containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Trifolium	*macrocephalum*		bighead clover	native	dry	seed requires treatment; seeds, containers	dry, often rocky soils, often amongst sagebrush or under yellow pine; requires good drainage and full sun; associates with N-fixing bacteria
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
Xerophyllum	*tenax*		beargrass	native	dry to moist	seed requires treatment; rhizome cuttings; containers	requires good drainage, often on steep slopes with shallow soils, tolerates serpentine and gabbro soils, prefers sun, moderately shade-tolerant
shrub, subshrub							
Arctostaphylos	*nevadensis*		pinemat manzanita	native	dry	seed requires treatment; containers	rocky soils, coniferous forest
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral
Ceanothus	*prostratus*		mahala mat	native	dry	seed requires treatment; containers	prostrate and mat-forming--good ground cover; open flats, coniferous forest; highly variable; requires good drainage, nitrogen-fixer

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Chamaebatia	*foliolosa*		mountain misery	native	dry to moist	seed requires treatment; rhizome cuttings, containers	provides good groundcover--may be invasive; coniferous forests; requires good drainage
Epilobium	*canum*	*Zauschneria californica*	California fuchsia	native	dry	no seed treatment; seeds, containers	dry slopes and ridges; different varieties; requires full sun and good drainage; spreads from underground stems; provides showy groundcover and is a good stabilizer
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Eriogonum	*umbellatum*		sulfur-flowered buckwheat	native	dry	no seed treatment (treatment increases viability); seeds, containers	many varieties; dry open, often rocky places; some varieties tolerate serpentine; is a good stabalizer and provides good cover
Eriophyllum	*lanatum*		woolly sunflower	native	dry to moist	no seed treatment; seeds, containers	many varieties in many habitats
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Penstemon	*newberryi*		mountain pride	native	dry	seed requires treatment; containers	granite rock outcrops, talus; requires good drainage
Salvia	*sonomensis*		creeping sage	native	dry	seed requires treatment; divisions; cuttings; containers	chaparral, oak woodland, and yellow pine forest; prostrate, mat-forming; requires good drainage, full sun, dry sites; provides a good groundcover; fire resistant if mowed and lightly irrigated; tolerates clay and serpentine soils
Symphoricarpos	*mollis*		creeping snowberry	native	moist	seed requires treatment, cuttings or divisions; containers	dry, part-shady conditions in woods; good slope cover
shrub, vine							
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
Vitis	*californica*		California wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; sprawling, climbing growth habit; tolerates most soil textures; sun or access to sun; fast-grower, forms groundcover if no support
shrub							
Acer	*circinatum*		vine maple	native	moist to wet	seed requires treatment; container	shaded streambanks

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Aesculus	*californicus*		buckeye	native	dry to moist	no seed treatment; seeds and containers	dry slopes, canyons, near streams
Amelanchier	*utahensis*		Utah serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open slopes, shrubland, pinyon/juniper woodland, coniferous forest
Arctostaphylos	*manzanita*		common manzanita	native	dry	seed requires treatment; containers	rocky soils, chaparral, woodland, forest
Arctostaphylos	*patula*		greenleaf manzanita	native	dry	seed requires treatment; seeds, containers	shrublands, open coniferous forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment
Artemisia	*cana ssp. bolanderi*		silver sagebrush	native	dry to moist	seeds	gravelly soils, meadows, streambanks
Artemisia	*tridentata*		sagebrush	native	dry	fresh seeds--no treatment, stored seeds--treatment; containers	dry soils in many scrubs, shrublands, and woodlands
Calycanthus	*occidentalis*		spicebush	native	moist	seed requires treatment; containers	moist, shady places along streams
Ceanothus	*cuneatus*		buckbrush	native	dry	seed requires treatment; containers	many varieties, variable, prostrate to subshrub to shrub; some serpentine tolerance; requires good drainage; widespread, nitrogen-fixer
Ceanothus	*integerrimus*		deer brush	native	dry	seed requires treatment; containers	dry slopes, ridges; highly variable; disturbed roadsides, nitrogen-fixer
Ceanothus	*velutinus var. velutinus*		tobacco bush	native	dry	seed requires treatment; containers	open, wooded slopes, disturbed areas; nitrogen-fixer
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; seeds require dormancy treatment; nitrogen-fixer; occurs in many habitats
Cercocarpus	*betuloides*		mountain mahogany	native	dry	no seed treatment; containers	chaparral, pine/oak woodland, coniferous forest; many varieties
Cercocarpus	*ledifolius*		curl-leaf mountain mahogany	native	dry	seed requires treatment; containers	deep soils, rocky slopes; requires good drainage; pinyon/juniper, sagebrush scrub, open pine forest

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related
Chrysothamnus	*viscidiflorus*		yellow rabbitbrush	native	dry	no seed treatment; seeds, containers	many subspecies; sagebrush, pinyon/juniper woodland
Cornus	*sericea ssp. sericea*	*Cornus stolonifera*	red osier dogwood	native	moist	seed requires treatment; stem cuttings, containers	many moist habitats; rooting stems
Corylus	*cornuta var. californica*		California hazelnut	native	moist	seed requires treatment; containers	riparian; shady places in many habitats
Dendromecon	*rigida*		bush poppy	native	dry	seed requires treatment; rooted stem cuttings, containers	dry slopes and washes, recent burns; requires good drainage
Eriodictyon	*californicum*		yerba santa	native	dry to moist	seed requires treatment; seeds, containers	open areas, slopes, fields, roadsides, woodland, chaparral; invasive after disturbance; requires good drainage
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Garrya	*fremontii*		mountain silktassel	native	dry to moist	seed requires treatment; containers	chaparral, foothill woodland, montane forest
Heteromeles	*arbutifolia*		toyon	native	dry to moist	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	chaparral, oak woodland, mixed-evergreen forest; requires full sun and good drainage
Holodiscus	*discolor*		oceanspray	native	moist	seed requires treatment; containers	moist woodland edges, rocky slopes
Oemleria	*cerasiformis*	*Osmoraonia c.*	oso berry	native	moist	seed requires treatment; plant divisions; containers	shaded coniferous forest and chaparral; may not do well on poor soils
Philadelphus	*lewisii*		mock orange	native	dry to moist	seed requires treatment; containers	variety of sites from rockslides and cliffs to along water courses; soils range from deep, rich alluvial loams to rocky or gravelly loams; full sun to part shade
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Potentilla	*fruticosa*		bush cinquefoil	native	moist to wet	no seed treatment (treatment increases viability); softwood cuttings; containers	meadows, rocks; fertile, moist, well-drained soil; full sun

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Purshia	*tridentata*		antelope bitterbrush	native	dry	seed requires treatment; containers	dry Joshua tree or pinyon-juniper woodland; requires good drainage and full sun; tolerates rocky, but not saline, soils; nitrogen-fixer
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Ribes	*aureum*		golden currant	native	moist	seed requires treatment; suckers or cuttings; containers	riparian areas and canyons; sun to part shade; fine- to coarse-textured loam soils
Ribes	*velutinum*		desert gooseberry	native	dry	seed requires treatment; containers	dry slopes and coarse soils in sagebrush steppe, juniper woodland, and pine forest
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rosa	*woodsii var. ultramontana*		woody rose	native	moist to wet	seed requires treatment; containers	moist areas in forest and riparian areas; good invader and stabilizer; requires good drainage; full sun on coast, part shade in interior
Rubus	*leucodermis*		blackcap raspberry	native	moist	seed requires treatment; cuttings, root divisions; containers	hillslopes, canyon flats, and steambanks in montane areas
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salix	*scouleriana*		Scouler's willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, forests; requires sun

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
Sambucus	*racemosa*		red elderberry	native	moist	seed requires treatment; stem cuttings, containers	moist places, especially riparian; coastal and montane varieties; important to wildlife
Spiraea	*douglasii*		western spirea	native	moist	seed requires treatment; containers	moist, open, sunny areas in coniferous forest, especially in riparian areas; requires good drainage
Stenotus	*acaulis*	*Haplopappus a.*	stenotus	native	dry	container	dry, rocky, open shrubland; mat-forming
Styrax	*officinalis var. redivivus*	*S. o. var. californica*	snowdrop bush	native	dry	seed requires treatment; containers	full sun to light shade; dry places in chaparral and woodland; tolerates drought, heat, and rocky soils
Vaccinium	*parvifolium*		red huckleberry	native	moist	no seed treatment, but may improve germination; cuttings, containers	moist, shaded woods
tree							
Abies	*concolor*		white fir	native	moist	seed requires treatment; tubelings, supercell	mixed conifer to lower red-fir forests
Acer	*macrophyllum*		big-leaf maple	native	moist to wet	seed requires treatment; container	riparian, streambanks, canyons
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands
Alnus	*rhombifloia*		white alder	native	moist	no seed treatment, but low viability; cuttings, containers	riparian; rivers and streams, nitrogen-fixer
Arbutus	*menziesii*		madrone	native	dry to moist	seed requires treatment; container	coniferous and oak forests
Betula	*occidentalis*		water birch	native	wet	seed requires treatment; containers	riparian, streamsides
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Chrysolepis	*chrysophylla*		chinquapin	native	dry to moist	fresh seeds--no treatment; containers	coniferous forest, closed-cone-pine forest, chaparral; one variety shrubby
Cornus	*nuttallii*		mountain dogwood	native	moist	seed requires treatment; containers	various woodlands and forest; requires shade
Fraxinus	*dipetala*		California ash	native	moist	seed requires treatment; containers	riparian, canyons, slopes, chaparral, oak/pine woodland

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Juniperus	*occidentalis var. occidentalis*		western juniper	native	dry	seed requires treatment; containers	dry slopes, flats, sagebrush, juniper woodlands; requires good drainage
Lithocarpus	*densiflorus*		tanoak, tanbark oak	native	dry to moist	fresh seeds--no treatment; containers, supercells	requires good drainage and part shade; associates with conifers and other hardwoods
Pinus	*attenuata*		knobcone pine	native	dry	seed requires treatment; containers	barren, rocky soils (often serpentine) in closed-cone pine forest and chaparral; tolerates fire; requires good drainage and full sun
Pinus	*contorta*		lodgepole pine	native	moist	fresh seeds-no treatment, stored seeds-treatment; containers	coastal to subalpine forest; many soil types; tolerates fire
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*lambertiana*		sugar pine	native	moist	seed requires treatment; cuttings possible; containers	mixed conifer and mixed evergreen forests; moist, steep, north- and east-facing slopes to more mesic south-facing slopes; requires good drainage; world's tallest pine
Pinus	*ponderosa*		ponderosa pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; grows on many soil types
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Populus	*tremuloides*		quaking aspen	native	moist	no seed treatment; best from stem cuttings	higher elevation riparian, moist openings, and slopes in forests, woodlands, and sagebrush steppe; cultivars used for phytoremediation; requires full sun and good drainage; good stabilizer; does not tolerate long-term flooding
Pseudotsuga	*menziesii var. menziesii*		Douglas-fir	native	moist	seed requires treatment (no treatment may be satisfactory)	mixed evergreen and mixed conifer forests; sun to part shade

Appendix A2	CASCADE RANGE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Quercus	*chrysolepis*		canyon live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	canyons, shaded slopes, chaparral, mixed evergreen forest, woodland; full sun to part shade; tolerates wide range of soil types, including rocky substrates, heavy clay, and serpentine
Quercus	*garryana*		Oregon oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes in woodland and mixed evergreen or conifer forest; tolerates poor soils; shrubby subspecies
Quercus	*kelloggii*		black oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes, valleys, woodland, coniferous forest; fire-related; requires good drainage, sun to part shade
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding
Quercus	*wislizenii*		interior live oak	native	dry	seed requires treatment if stored; acorns, containers	interior canyons, slopes, and valleys; requires full sun and good drainage
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Umbellularia	*californica*		California bay	native	dry to moist	seed requires treatment; untreated fresh seed yields slow germination; containers	riparian canyons (tree); chaparral (shrub); shade to sun; loam, sandy loam, or clay soils, tolerates serpentine; releases terpenes that inhibit weeds

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Anthoxanthum	*ordoratum*		sweet vernal grass	exotic	moist to wet	no seed treatment; seeds	disturbed sites; could be used for one year channel protection
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*occidentalis*	*Stipa o.*	needlegrass	native	dry	no seed treatment; seeds, containers	open dry sites, sagebrush scrub, coniferous forest, alpine
Achnatherum	*speciosum*	*Stipa s.*	desert needlegrass	native	dry	no seed treatment; seeds, containers	rocky slopes, canyons, washes, or sandy areas of sagebrush scrub; requires good drainage and full sun; good stabilizer
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Agrostis	*scabra*		ticklegrass	native	moist to wet	no seed treatment; seeds	roadsides, meadows, forests; could be used for multi-year channel protection; robust invader

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Alopecurus	*geniculatus*		water foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader
Bromus	*inermis ssp. inermis*		smooth brome	exotic	moist	no seed treatment; seed	rhizomatous; meadows, ditches, fields
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Deschampsia	*caespitosa ssp. caespitosa*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, containers	meadows, streambanks, coastal marsh, forests, alpine; densely-tufted bunchgrass, excellent stabilizer; can withstand summer drought if saturated in spring
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Elymus	*trachycaulus ssp. trachycaulus*	*Agropyron subsecundus*	big squirreltail	native	dry to moist	no seed treatment; seeds, containers	dry to moist, open areas, forest, woodland
Elytrigia	*intermedia*	*Agropyron i.*	intermediate wheatgrass	exotic	dry to moist	no seed treatment; seeds	open areas, slopes; highly invasive, used for forage and erosion control
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives
Festuca	*californica*		California fescue	native	moist	no seed treatment; seeds, container	open forest, chaparral
Festuca	*idahoensis*		Idaho fescue	native	dry to moist	no seed treatment; seeds, containers	dry open or shady places
Festuca	*occidentalis*		western fescue	native	moist	no seed treatment; seeds, container	open pine/oak woodland, redwood forest

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Festuca	*rubra*		red fescue	native	dry	no seed treatment; seeds, containers	varieties available (beware of less adaptive non-natives); sand dunes, grassland, subalpine forest; loosely tufted groundcover
Festuca	*trachyphylla*		hard fescue	exotic	mesic	no seed treatment; seeds	open places, slopes; invasive
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Melica	*californica*		California melic	native	dry	no seed treatment; seeds or containers	with short rhizomes, requires good drainage and full sun; tolerates serpentine
Melica	*imperfecta*		Coast Range oniongrass	native	dry	no seed treatment; seeds or containers	loosely tufted bunchgrass, tolerant of serpentine
Melica	*torreyana*		Torrey's melic	native	dry	no seed treatment; seeds or containers	chaparral, coniferous forest; part shade
Muhlenbergia	*rigens*		deergrass	native	moist	no seed treatment; vegetatively by plant divisions; containers	along streams, meadow edges, hillside seeps, ditches, and roads; dry, damp, or moist conditions; full sun to part shade; withstands short duration flooding; tolerates flooding; forms dense clumps
Nassella	*pulchra*	*Stipa p.*	purple needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; adapted to clay soils, tolerant of summer drought and heat, tolerant of serpentine, tolerant of poor soils
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
herb, perennial							
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds or container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Anaphalis	*margaritacea*		pearly everlasting	native	moist	no seed treatment; seeds	woods, roadsides, disturbance
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds and containers	open to shady places in drainages
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Balsamorhiza	*sagittata*		balsamroot	native	dry	seed requires treatment; containers	open forests, scrub
Camassia	*quamash ssp. quamash*		camas	native	wet	seed requires treatment; containers	damp forests, wet meadows, streamsides

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Carex	*barbarae*		Santa Barbara sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; seasonally wet places; invasive
Carex	*nebrascensis*		Nebraska sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; meadows and swamps
Carex	*nudata*		sedge	native	wet	no seed treatment; seeds, cuttings, containers	clumped, not rhizomatous; grass-like; streambeds
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection
Carex	*tumulicola*		Berkeley sedge	native	moist	no seed treatment; seeds, cuttings, containers	grass-like and rhizomatous; meadows, open woodlands
Eleocharis	*macrostachya*		spike rush	native	wet	seeds/plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Epilobium	*angustifolium ssp. circumvagum*		fireweed	native	dry to moist	no seed treatment; seeds, containers	open places, roadsides; can be invasive, especially after fire
Fragaria	*vesca*		woodland strawberry	native	moist	no seed treatment; containers	partial shade in forests
Heuchera	*micrantha*		alumroot	native	moist to wet	no seed treatment; rooted stem cuttings, containers	moist rocky banks and cliffs; good ground cover
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Linnea	*borealis var. longiflora*		twinflower	native	moist	stolon divisions; containers	moist shady places in coniferous forest; requires shade and good drainage; groundcover
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lupinus	*albicaulis*		sickle-keeled lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	dry slopes and openings; requires full sun; good colonizer, nitrogen-fixer
Lupinus	*andersonii*		Anderson's lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	dry slopes, often under pines, nitrogen-fixer
Lupinus	*argenteus*		mountain lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	montane forest and sagebrush scrub, nitrogen-fixer
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Monardella	*odoratissima*		coyote mint	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	gravelly flats and dry slopes in montane forest and sagebrush scrub
Monardella	*villosa*		coyote mint	native	dry	no seed treatment; vegetatively from rooted side shoots; seeds, containers	dry, rocky or gravelly places in oak woodland, chaparral, and montane forest; full sun to part shade
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase viability); seed, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils
Potentilla	*gracillis*		slender cinquefoil	native	moist	no seed treatment; seeds	mostly moist places in meadows and open forests; full sun
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Sedum	*spathulifolium*		creeping stonecrop	native	dry to moist	containers	outcrops in forest communities, often in shade; requires good drainage

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds or containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
Wyethia	*angustifolia*		narrowleaf mules ears	native	dry	seed treatment not necessary, but may help; seeds, containers	requires full sun and good drainage, grassland
Xerophyllum	*tenax*		beargrass	native	dry to moist	seed requires treatment; rhizome cuttings; containers	requires good drainage, often on steep slopes with shallow soils, tolerates serpentine and gabbro soils, prefers sun, moderately shade-tolerant
shrub, subshrub							
Acomptopappus	*sphaerocephlus*		goldenhead	native	dry	containers	gravelly or rocky soils in deserts to juniper woodlands
Arctostaphylos	*nevadensis*		pinemat manzanita	native	dry	seed requires treatment; containers	rocky soils, coniferous forest
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral
Berberis	*nervosa*		barberry	native	moist	seed requires treatment; containers	coniferous forest
Ceanothus	*cordulatus*		mountain whitethorn	native	dry	seed requires treatment; containers	can be prostate; rocky ridges, open pine forests; requires good drainage, nitrogen-fixer
Ceanothus	*prostratus*		mahala mat	native	dry	seed requires treatment; containers	prostrate and mat-forming--good ground cover; open flats, coniferous forest; highly variable; requires good drainage, nitrogen-fixer
Chamaebatia	*foliolosa*		mountain misery	native	dry to moist	seed requires treatment; rhizome cuttings, containers	provides good groundcover--may be invasive; coniferous forests; requires good drainage

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Epilobium	*canum*	*Zauschneria californica*	California fuchsia	native	dry	no seed treatment; seeds, containers	dry slopes and ridges; different varieties; requires full sun and good drainage; spreads from underground stems; provides showy groundcover and is a good stabilizer
Ericameria	*linearifolia*	*Haplopappus l.*	narrowleaf goldenbush	native	dry	no seed treatment; seeds, containers	dry slopes, valleys
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Eriogonum	*umbellatum*		sulfur-flowered buckwheat	native	dry	no seed treatment (treatment increases viability); seeds, containers	many varieties; dry open, often rocky places; some varieties tolerate serpentine; is a good stabilizer and provides good cover
Eriophyllum	*conferiflorum*		golden yarrow	native	dry	no seed treatment (treatment increases viability); seeds, containers	many dry habitats
Eriophyllum	*lanatum*		woolly sunflower	native	dry to moist	no seed treatment; seeds, containers	many varieties in many habitats
Frankenia	*salina*		alkali-heath	native	moist to wet	no seed treatment; containers	mat-forming in salt marshes, alkali flats; good ground cover
Lepechinia	*calycina*		pitcher sage	native	dry	seed requires treatment; seeds, containers	rocky slopes, chaparral, woodland; requires good drainage
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Lessingia	*filaginifolia*	*Corethrogyne f.*	California-aster	native	moist		highly variable; coastal scrub, oak woodlands, grasslands
Lonicera	*hispidula var. vacillans*		Californica honeysuckle	native	moist	seed requires treatment; cuttings; containers	along streams and on slopes in coniferous and foothill woodlands; requires shade; good ground cover; tolerates clay soils
Mimulus	*aurantiacus*	*Diplacus, Mimulus longiflorus*	sticky monkeyflower	native	dry	no seed treatment; seeds or containers	consists of many different varieties; requires good drainage; requires full sun near coast, yet tolerates some shade inland

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Penstemon	*newberryi*		mountain pride	native	dry	seed requires treatment; containers	granite rock outcrops, talus; requires good drainage
Salvia	*sonomensis*		creeping sage	native	dry	seed requires treatment; divisions; cuttings; containers	chaparral, oak woodland, and yellow pine forest; prostrate, mat-forming; requires good drainage, full sun, dry sites; provides a good groundcover; fire resistant if mowed and lightly irrigated; tolerates clay and serpentine soils
Symphoricarpos	*mollis*		creeping snowberry	native	moist	seed requires treatment, cuttings or divisions; containers	dry, part-shady conditions in woods; good slope cover
shrub, vine							
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
Vitis	*californica*		California wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; sprawling, climbing growth habit; tolerates most soil textures; sun or access to sun; fast-grower, forms groundcover if no support
shrub							
Acer	*circinatum*		vine maple	native	moist to wet	seed requires treatment; container	shaded streambanks
Adenostoma	*fasciculatum*		chamise	native	dry	fresh seeds require no treatment; seeds, containers	dry slopes, chaparral
Aesculus	*californicus*		buckeye	native	dry to moist	no seed treatment; seeds and containers	dry slopes, canyons, near streams
Amelanchier	*alnifolia*		western serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open shrublands and coniferous forest
Amelanchier	*utahensis*		Utah serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open slopes, shrubland, pinyon/juniper woodland, coniferous forest
Arctostaphylos	*manzanita*		common manzanita	native	dry	seed requires treatment; containers	rocky soils, chaparral, woodland, forest
Arctostaphylos	*patula*		greenleaf manzanita	native	dry	seed requires treatment; seeds, containers	shrublands, open coniferous forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Baccharis	*pilularis*	*B. p. var. consanguinea*	coyote bush	native	dry to moist	no seed treatment; seed, containers	coastal bluffs to woodlands, sometimes on serpentine; requires good drainage; provides good groundcover and good stabilization; some varieties are serpentine tolerant
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Calycanthus	*occidentalis*		spicebush	native	moist	seed requires treatment; containers	moist, shady places along streams
Carpenteria	*californica*		tree anemone	native	dry to moist	no seed treatment; containers	fire-resistant, stump-sprouters; streambanks, chaparral, oak woodland
Ceanothus	*cuneatus*		buckbrush	native	dry	seed requires treatment; containers	many varieties, variable, prostrate to subshrub to shrub; some serpentine tolerance; requires good drainage; widespread, nitrogen-fixer
Ceanothus	*integerrimus*		deer brush	native	dry	seed requires treatment; containers	dry slopes, ridges; highly variable; disturbed roadsides, nitrogen-fixer
Ceanothus	*velutinus var. velutinus*		tobacco bush	native	dry	seed requires treatment; containers	open, wooded slopes, disturbed areas; nitrogen-fixer
Cephalanthus	*occidentalis var. californicus*		buttonwillow	native	moist to wet	no seed treatment; cuttings, containers	riparian, lake, streamedges, drainages; can withstand reservoir drawdown
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; seeds require dormancy treatment; nitrogen-fixer; occurs in many habitats
Cercocarpus	*betuloides*		mountain mahogany	native	dry	no seed treatment; containers	chaparral, pine/oak woodland, coniferous forest; many varieties
Cornus	*sericea ssp. sericea*	*Cornus stolonifera*	red osier dogwood	native	moist	seed requires treatment; stem cuttings, containers	many moist habitats; rooting stems
Corylus	*cornuta var. californica*		California hazelnut	native	moist	seed requires treatment; containers	riparian; shady places in many habitats
Dendromecon	*rigida*		bush poppy	native	dry	seed requires treatment; rooted stem cuttings, containers	dry slopes and washes, recent burns; requires good drainage

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Eriodictyon	*californicum*		yerba santa	native	dry to moist	seed requires treatment; seeds, containers	open areas, slopes, fields, roadsides, woodland, chaparral; invasive after disturbance; requires good drainage
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Garrya	*fremontii*		mountain silktassel	native	dry to moist	seed requires treatment; containers	chaparral, foothill woodland, montane forest
Heteromeles	*arbutifolia*		toyon	native	dry to moist	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	chaparral, oak woodland, mixed-evergreen forest; requires full sun and good drainage
Holodiscus	*discolor*		oceanspray	native	moist	seed requires treatment; containers	moist woodland edges, rocky slopes
Holodiscus	*microphyllus*		rock spiraea	native	dry to moist	seed requires treatment; containers	rocky places, outcrops; a few varieties
Lonicera	*involucrata*		twinberry	native	moist to wet	seed requires treatment; cuttings; containers	moist places, such as riparian areas; sun to part shade
Oemleria	*cerasiformis*	*Osmoraonia c.*	oso berry	native	moist	seed requires treatment; plant divisions; containers	shaded coniferous forest and chaparral; may not do well on poor soils
Philadelphus	*lewisii*		mock orange	native	dry to moist	seed requires treatment; containers	variety of sites from rockslides and cliffs to along water courses; soils range from deep, rich alluvial loams to rocky or gravelly loams; full sun to part shade
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Potentilla	*fruticosa*		bush cinquefoil	native	moist to wet	no seed treatment (treatment increases viability); softwood cuttings; containers	meadows, rocks; fertile, moist, well-drained soil; full sun
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Quercus	*berberidifolia*	*Q. dumosa misapplied*	scrub oak	native	dry to moist	seed requires treatment if stored; acorns, containers	dry slopes in chaparral; requires good drainage and full sun; some ecotypes acid-tolerant
Quercus	*vaccinifolia*		huckleberry oak	native	dry	seed requires treatment if stored; acorns, containers	steep slopes and ridges in coniferous forest and subalpine areas; tolerates rocky and serpentine soils
Rhamnus	*ilicifolia*	*R. crocea ssp. I.*	hollyleaf redberry	native	dry	fresh seeds require no treatment; containers	chaparral, montane forests, good on dry banks
Rhamnus	*tomentella ssp. tomentella*	*R. californica ssp. t.*	hoary coffeeberry	native	dry	fresh seeds require no treatment; containers	chaparral and woodlands; requires good drainage and sun
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Ribes	*aureum*		golden currant	native	moist	seed requires treatment; suckers or cuttings; containers	riparian areas and canyons; sun to part shade; fine- to coarse-textured loam soils
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rosa	*woodsii var. ultramontana*		woody rose	native	moist to wet	seed requires treatment; containers	moist areas in forest and riparian areas; good invader and stabilizer; requires good drainage; full sun on coast, part shade in interior
Rubus	*leucodermis*		blackcap raspberry	native	moist	seed requires treatment; cuttings, root divisions; containers	hillslopes, canyon flats, and steambanks in montane areas
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salix	*scouleriana*		Scouler's willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, forests; requires sun
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
Sambucus	*racemosa*		red elderberry	native	moist	seed requires treatment; stem cuttings, containers	moist places, especially riparian; coastal and montane varieties; important to wildlife
Spiraea	*douglasii*		western spirea	native	moist	seed requires treatment; containers	moist, open, sunny areas in coniferous forest, especially in riparian areas; requires good drainage
Stenotus	*acaulis*	*Haplopappus a.*	stenotus	native	dry	container	dry, rocky, open shrubland; mat-forming
Styrax	*officinalis var. redivivus*	*S. o. var. californica*	snowdrop bush	native	dry	seed requires treatment; containers	full sun to light shade; dry places in chaparral and woodland; tolerates drought, heat, and rocky soils
Vaccinium	*parvifolium*		red huckleberry	native	moist	no seed treatment, but may improve germination; cuttings, containers	moist, shaded woods
tree							
Acer	*macrophyllum*		big-leaf maple	native	moist to wet	seed requires treatment; container	riparian, streambanks, canyons
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands
Alnus	*rhombifloia*		white alder	native	moist	no seed treatment, but low viability; cuttings, containers	riparian; rivers and streams, nitrogen-fixer
Arbutus	*menziesii*		madrone	native	dry to moist	seed requires treatment; container	coniferous and oak forests
Betula	*occidentalis*		water birch	native	wet	seed requires treatment; containers	riparian, streamsides
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Chrysolepis	*chrysophylla*		chinquapin	native	dry to moist	fresh seeds--no treatment; containers	coniferous forest, closed-cone-pine forest, chaparral; one variety shrubby

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Cornus	*nuttallii*		mountain dogwood	native	moist	seed requires treatment; containers	various woodlands and forest; requires shade
Fraxinus	*dipetala*		California ash	native	moist	seed requires treatment; containers	riparian, canyons, slopes, chaparral, oak/pine woodland
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Fraxinus	*velutina*		ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Pinus	*attenuata*		knobcone pine	native	dry	seed requires treatment; containers	barren, rocky soils (often serpentine) in closed-cone pine forest and chaparral; tolerates fire; requires good drainage and full sun
Pinus	*contorta*		lodgepole pine	native	moist	fresh seeds-no treatment, stored seeds-treatment; containers	coastal to subalpine forest; many soil types; tolerates fire
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*lambertiana*		sugar pine	native	moist	seed requires treatment; cuttings possible; containers	mixed conifer and mixed evergreen forests; moist, steep, north- and east-facing slopes to more mesic south-facing slopes; requires good drainage; world's tallest pine
Pinus	*ponderosa*		ponderosa pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; grows on many soil types
Pinus	*sabiniana*		foothill pine, gray pine	native	dry	seed requires treatment; containers	dry slopes and ridges in foothill woodland, chaparral, infertile soils in mixed conifer and hardwood forests; requires good drainage and full sun
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Populus	*tremuloides*		quaking aspen	native	moist	no seed treatment; best from stem cuttings	higher elevation riparian, moist openings, and slopes in forests, woodlands, and sagebrush steppe; cultivars used for phytoremediation; requires full sun and good drainage; good stabilizer; does not tolerate long-term flooding
Pseudotsuga	*menziesii var. menziesii*		Douglas-fir	native	moist	seed requires treatment (no treatment may be satisfactory)	mixed evergreen and mixed conifer forests; sun to part shade
Quercus	*chrysolepis*		canyon live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	canyons, shaded slopes, chaparral, mixed evergreen forest, woodland; full sun to part shade; tolerates wide range of soil types, including rocky substrates, heavy clay, and serpentine
Quercus	*douglasii*		blue oak	native	dry	seed requires treatment if stored; acorns, containers	dry slopes in woodlands of interior foothills; requires full sun and good drainage
Quercus	*kelloggii*		black oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes, valleys, woodland, coniferous forest; fire-related; requires good drainage, sun to part shade
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding
Quercus	*wislizenii*		interior live oak	native	dry	seed requires treatment if stored; acorns, containers	interior canyons, slopes, and valleys; requires full sun and good drainage
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Torreya	*californica*		California nutmeg	native	moist	seed requires treatment; containers	shady canyons of forests and woodlands, best in high humidity areas with good drainage

Appendix A3	SIERRA NEVADA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Umbellularia	*californica*		California bay	native	dry to moist	seed requires treatment; untreated fresh seed yields slow germination; containers	riparian canyons (tree); chaparral (shrub); shade to sun; loam, sandy loam, or clay soils, tolerates serpentine; releases terpenes that inhibit weeds

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
grass, perennial							
Achnatherum	*hymenoides*	*Oryzopsis hymenoides*	Indian ricegrass	native	dry	fresh seeds require no treatment; seeds and containers	dry, sandy soil, desert shrub, sagebrsuh scrub, pinyon/juniper
Achnatherum	*occidentalis*	*Stipa o.*	needlegrass	native	dry	no seed treatment; seeds, containers	open dry sites, sagebrush scrub, coniferous forest, alpine
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Alopecurus	*geniculatus*		water foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Bromus	*inermis ssp. inermis*		smooth brome	exotic	moist	no seed treatment; seed	rhizomatous; meadows, ditches, fields
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Elymus	*elymoides ssp. elymoides*	*Sitanion hystrix*	squirreltail	native	dry	no seed treatment; seeds, containers	bunchgrass; best in open, very dry situations and on poor soils, serpentine tolerant
Elytrigia	*intermedia*	*Agropyron i.*	intermediate wheatgrass	exotic	dry to moist	no seed treatment; seeds	open areas, slopes; highly invasive, used for forage and erosion control
Festuca	*idahoensis*		Idaho fescue	native	dry to moist	no seed treatment; seeds, containers	dry open or shady places
Festuca	*occidentalis*		western fescue	native	moist	no seed treatment; seeds, container	open pine/oak woodland, redwood forest
Hesperostipa	*comata*	*Stipa c.*	needle and thread	native	dry	no seed treatment; seeds, containers	grassland, sagebrush shrubland, pinyon/juniper woodland
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Pascopyrum	*smithii*	*Agropyron s.*	western wheatgrass	native	dry to moist	no seed treatment; rhizome divisions; seeds, containers	dry, alkaline soils, flats; tolerant of periodic flooding and poor drainage
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Pseudoroegneria	*spicata ssp. spicata*	*Agropyron s.*	bluebunch wheatgrass	native	dry	no seed treatment; seeds	sagebrush steppe, open woodland; requires good drainage and full sun
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
herb, annual							
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Plantago	*ovata*	*P. insularis*	desert plantain	native	dry	seed requires treatment; seeds	sandy or gravelly soils in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and coastal strand; full sun to part shade; good colonizer
Salvia	*columbariae*		chia	native	dry	seed germination often improved with treatment; seeds or containers	dry, open, often disturbed places in scrub and chaparral; requires full sun and good drainage; gravelly slopes and sandy soils
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer
herb, perennial							
Anaphalis	*margaritacea*		pearly everlasting	native	moist	no seed treatment; seeds	woods, roadsides, disturbance
Argemone	*munita*		prickly poppy	native	dry	no seed treatment; seeds	open area, disturbance
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Balsamorhiza	*sagittata*		balsamroot	native	dry	seed requires treatment; containers	open forests, scrub
Camassia	*quamash ssp. quamash*		camas	native	wet	seed requires treatment; containers	damp forests, wet meadows, streamsides
Carex	*nebrascensis*		Nebraska sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; meadows and swamps
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection
Castilleja	*angustifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	sagebrush scrub, pinyon/juniper woodland
Castilleja	*linariifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	dry plains, rocky slopes, sagebrush shrubland, pinyon/juniper woodland
Eleocharis	*macrostachya*		spike rush	native	wet	seeds/plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Lupinus	*argenteus*		mountain lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	montane forest and sagebrush scrub, nitrogen-fixer
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Lupinus	*saxosus*		stony-ground lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	open areas in sagebrush scrub, typically on gravelly or rocky substrates, nitrogen-fixer
Monardella	*odoratissima*		coyote mint	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	gravelly flats and dry slopes in montane forest and sagebrush scrub
Penstemon	*speciosus*		showy penstemon	native	dry	seed requires treatment; seed, containers	open sagebrush scrub to subalpine forest; requires good drainage and full sun
Potentilla	*gracillis*		slender cinquefoil	native	moist	no seed treatment; seeds	mostly moist places in meadows and open forests; full sun
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Trifolium	*macrocephalum*		bighead clover	native	dry	seed requires treatment; seeds, containers	dry, often rocky soils, often amongst sagebrush or under yellow pine; requires good drainage and full sun; associates with N-fixing bacteria
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
shrub, subshrub							
Acomptopappus	*sphaerocephlus*		goldenhead	native	dry	containers	gravelly or rocky soils in deserts to juniper woodlands

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Artemisia	*arbuscula*		low sagebrush	native	dry		clay soils, valleys, slopes
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral
Ceanothus	*prostratus*		mahala mat	native	dry	seed requires treatment; containers	prostrate and mat-forming--good ground cover; open flats, coniferous forest; highly variable; requires good drainage, nitrogen-fixer
Krascheninnikovia	*lanata*	*Ceratoidea l., Eurotia l.*	winter fat	native	dry	no seed treatment; seeds, containers	rocky to clay soils, flats, gentle slopes; requires good drainage and full sun
Lepidium	*fremontii*		peppergrass	native	dry	stored seeds--no treatment; seeds, containers	sandy washes, barren knolls, gravelly soils, rocky slopes, ridges; requires well-drained soils
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
shrub							
Amelanchier	*alnifolia*		western serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open shrublands and coniferous forest
Amelanchier	*utahensis*		Utah serviceberry	native	dry to moist	seed requires treatment; seeds, containers	open slopes, shrubland, pinyon/juniper woodland, coniferous forest
Arctostaphylos	*patula*		greenleaf manzanita	native	dry	seed requires treatment; seeds, containers	shrublands, open coniferous forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment
Artemisia	*cana ssp. bolanderi*		silver sagebrush	native	dry to moist	seeds	gravelly soils, meadows, streambanks
Artemisia	*tridentata*		sagebrush	native	dry	fresh seeds--no treatment, stored seeds--treatment; containers	dry soils in many scrubs, shrublands, and woodlands
Atriplex	*canescens*		four-wing saltbush	native	dry	stored seeds--no treatment; seeds, containers	dry slopes, flats, and shrublands; good stabilizer and invader in desert areas
Atriplex	*confertifolia*		shadscale	native	dry	stored seeds--no treatment; containers	alkaline flats, shrubland, pinyon/juniper
Atriplex	*gardneri*		Gardner's saltbush	native	dry	stored seeds--no treatment; containers	alkaline soils, sagebrush scrub

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Atriplex	*hymenolytra*		desert holly	native	dry	stored seeds--no treatment; containers	shrublands, washes
Atriplex	*lentiformis ssp. lentiformis*		quailbush	native	dry	no seed treatment; seeds, containers;	requires full sun and good drainage; alkaline and saline tolerant
Atriplex	*lentiformis ssp. torreyi*	*A. torreyi*	big saltbush	native	moist	no seed treatment; seeds, containers	alkaline flats, dry lakes, washes
Atriplex	*polycarpa*		alkali saltbush	native	dry	no seed treatment; seeds	alkaline flats, dry lakes
Cercocarpus	*betuloides*		mountain mahogany	native	dry	no seed treatment; containers	chaparral, pine/oak woodland, coniferous forest; many varieties
Cercocarpus	*ledifolius*		curl-leaf mountain mahogany	native	dry	seed requires treatment; containers	deep soils, rocky slopes; requires good drainage; pinyon/juniper, sagebrush scrub, open pine forest
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related
Chrysothamnus	*viscidiflorus*		yellow rabbitbrush	native	dry	no seed treatment; seeds, containers	many subspecies; sagebrush, pinyon/juniper woodland
Ephedra	*viridis*		green mormon tea	native	dry	seed requires treatment; containers	sagebrush scrub, creosote-bush scrub, pinyon/juniper woodland
Fallugia	*paradoxa*		Apache plume	native	dry	no seed treatment; container	dry, rocky slopes in pinyon/juniper woodland
Grayia	*spinosa*		spiny hopsage	native	dry	no seed treatment (treatment increases viability); containers	sandy to gravelly soils, shrubland, pinyon/juniper woodland
Holodiscus	*microphyllus*		rock spiraea	native	dry to moist	seed requires treatment; containers	rocky places, outcrops; a few varieties
Lycium	*andersonii*		Anderson's box thorn	native	dry	no seed treatment; seeds or containers	gravelly or rocky slopes, washes
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Prunus	*andersonii*		desert peach	native	dry	seed requires treatment; containers	rocky slopes and flats in sagebrush steppe and pinyon-juniper woodland; requires good drainage and full sun

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Purshia	*tridentata*		antelope bitterbrush	native	dry	seed requires treatment; containers	dry Joshua tree or pinyon-juniper woodland; requires good drainage and full sun; tolerates rocky, but not saline, soils; nitrogen-fixer
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Ribes	*aureum*		golden currant	native	moist	seed requires treatment; suckers or cuttings; containers	riparian areas and canyons; sun to part shade; fine- to coarse-textured loam soils
Ribes	*velutinum*		desert gooseberry	native	dry	seed requires treatment; containers	dry slopes and coarse soils in sagebrush steppe, juniper woodland, and pine forest
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rosa	*woodsii var. ultramontana*		woody rose	native	moist to wet	seed requires treatment; containers	moist areas in forest and riparian areas; good invader and stabilizer; requires good drainage; full sun on coast, part shade in interior
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salvia	*dorrii*		desert sage	native	dry	no seed treatment; seeds, containers	dry, rocky places; grows well on sand, volcanic rock, & decomposed granite; requires good drainage
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
Sarcobatus	*vermiculatus*		greasewood	native	dry to moist	seed requires treatment; seeds or containers	alkaline soils, dry lakes, washes, shrubland; deep taproot

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Stenotus	*acaulis*	*Haplopappus a.*	stenotus	native	dry	container	dry, rocky, open shrubland; mat-forming
Symphoricarpos	*longiflorus*		fragrant snowberry	native	dry	seed requires treatment; possible vegetative prop. by dividing rhizomes; containers	rocky slopes and washes, typically in pinyon-juniper woodland
Tetradymia	*canescens*		horsebrush	native	dry	seed or basal root sprouts; seed, containers	sandy and rocky soils in sagebrush scrub and pinyon/juniper woodland
tree							
Abies	*concolor*		white fir	native	moist	seed requires treatment; tubelings, supercell	mixed conifer to lower red-fir forests
Betula	*occidentalis*		water birch	native	wet	seed requires treatment; containers	riparian, streamsides
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Juniperus	*occidentalis var. occidentalis*		western juniper	native	dry	seed requires treatment; containers	dry slopes, flats, sagebrush, juniper woodlands; requires good drainage
Juniperus	*osteosperma*		Utah juniper	native	dry	seed requires treatment; containers	pinyon/juniper woodlands
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*lambertiana*		sugar pine	native	moist	seed requires treatment; cuttings possible; containers	mixed conifer and mixed evergreen forests; moist, steep, north- and east-facing slopes to more mesic south-facing slopes; requires good drainage; world's tallest pine
Pinus	*monophylla*		singleleaf pinyon pine	native	dry	seed requires treatment unless max. germinating temp. is below 73 deg. F; containers	upland bajadas and mountain slopes above the valley floor in pinyon-juniper woodland; requires good drainage; slow growing
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation

Appendix A4	GREAT BASIN FLORISTIC PROVINCE						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Populus	*tremuloides*		quaking aspen	native	moist	no seed treatment; best from stem cuttings	higher elevation riparian, moist openings, and slopes in forests, woodlands, and sagebrush steppe; cultivars used for phytoremediation; requires full sun and good drainage; good stabilizer; does not tolerate long-term flooding
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Anthoxanthum	*ordoratum*		sweet vernal grass	exotic	moist to wet	no seed treatment; seeds	disturbed sites; could be used for one year channel protection
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Agrostis	*scabra*		ticklegrass	native	moist to wet	no seed treatment; seeds	roadsides, meadows, forests; could be used for multi-year channel protection; robust invader
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Alopecurus	*geniculatus*		water foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader
Calamagrostis	*nutkaensis*		Pacific reedgrass	native	moist to wet	no seed treatment; seeds, containers	bunchgrass; wet areas, beaches, dunes, coastal woodland
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Deschampsia	*caespitosa ssp. caespitosa*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, containers	meadows, streambanks, coastal marsh, forests, alpine; densely-tufted bunchgrass, excellent stabilizer; can withstand summer drought if saturated in spring
Deschampsia	*caespitosa ssp. holciformis*		tufted hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	coastal marshes and meadows; clump forming, excellent stabilizer, tolerates saline water and saline soil
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*californicus*	*Hystrix c.*	bottlebrush grass	native	moist	no seed treatment; seeds, containers	coniferous forest
Elymus	*elymoides ssp. elymoides*	*Sitanion hystrix*	squirreltail	native	dry	no seed treatment; seeds, containers	bunchgrass; best in open, very dry situations and on poor soils, serpentine tolerant
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Elymus	*trachycaulus ssp. trachycaulus*	*Agropyron subsecundus*	big squirreltail	native	dry to moist	no seed treatment; seeds, containers	dry to moist, open areas, forest, woodland
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Festuca	*californica*		California fescue	native	moist	no seed treatment; seeds, container	open forest, chaparral
Festuca	*idahoensis*		Idaho fescue	native	dry to moist	no seed treatment; seeds, containers	dry open or shady places
Festuca	*occidentalis*		western fescue	native	moist	no seed treatment; seeds, container	open pine/oak woodland, redwood forest
Festuca	*rubra*		red fescue	native	dry	no seed treatment; seeds, containers	varieties available (beware of less adaptive non-natives); sand dunes, grassland, subalpine forest; loosely tufted groundcover
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Leymus	*triticoides*	*Elymus triticoides*	creeping wildrye	native	moist to wet	no seed treatment; seeds (but germination poor), containers, plugs; grown from rhizomes	good groundcover and good stabilizer, highly rhizomatous, tolerates alkaline soils and high summer temperatures, good for streambanks
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Melica	*californica*		California melic	native	dry	no seed treatment; seeds or containers	with short rhizomes, requires good drainage and full sun; tolerates serpentine
Melica	*imperfecta*		Coast Range oniongrass	native	dry	no seed treatment; seeds or containers	loosely tufted bunchgrass, tolerant of serpentine
Melica	*torreyana*		Torrey's melic	native	dry	no seed treatment; seeds or containers	chaparral, coniferous forest; part shade
Monanthochloe	*littoralis*		shoregrass	native	wet	best grown from rhizomes	good groundcover and stabilizer, tolerates very saline soils and coastal salt marsh conditions

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Muhlenbergia	*rigens*		deergrass	native	moist	no seed treatment; vegetatively by plant divisions; containers	along streams, meadow edges, hillside seeps, ditches, and roads; dry, damp, or moist conditions; full sun to part shade; withstands short duration flooding; tolerates flooding; forms dense clumps
Nassella	*cernua*	*Stipa c.*	nodding needlegrass	native	dry	no seed treatment; seed, containers	bunchgrass; dry slopes in chaparral, grassland, and juniper woodland; best on well-drained sandy loam, but tolerates rocky soil; full sun to part shade; does well on poor soils; good stabilizer
Nassella	*lepida*	*Stipa l.*	foothill needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; dry slopes, chaparral, open woods; full sun to part shade; good bank stabilizer
Nassella	*pulchra*	*Stipa p.*	purple needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; adapted to clay soils, tolerant of summer drought and heat, tolerant of serpentine, tolerant of poor soils
Phalaris	*californica*		canary grass	native	moist	no seed treatment; seeds	moist areas in meadows and woodlands
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
Spartina	*foliosa*		cordgrass	native	wet	seed treatment required; rhizome divisions; containers, plugs	dense, monospecific stands in tidal zone of salt marshes
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Lasthenia	*glabrata*		goldfields	native	wet		saline places, vernal pools; requires full sun
Layia	*platyglossa*		tidy-tips	native	dry to moist		many habitats; requires full sun
Linanthus	*grandiflorus*		large-flowered linanthus	native	dry	seeds	generally in sandy soil on open, grassy flats; requires full sun and good drainage
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Lupinus	*bicolor*		pigmy-leaved lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	requires full sun and good drainage; is a good stabilizer; nitrogen-fixer
Lupinus	*microcarpus*	*L. densiflorus*	chick lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	requires full sun; does well on poor soils; nitrogen-fixer
Lupinus	*succulentus*		arroyo lupine	native	dry	seed requires treatment; seeds)	open or disturbed areas; requires full sun; is a good stabilizer; does well on poor soils, nitrogen-fixer
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Plantago	*ovata*	*P. insularis*	desert plantain	native	dry	seed requires treatment; seeds	sandy or gravelly soils in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and coastal strand; full sun to part shade; good colonizer
Salvia	*columbariae*		chia	native	dry	seed germination often improved with treatment; seeds or containers	dry, open, often disturbed places in scrub and chaparral; requires full sun and good drainage; gravelly slopes and sandy soils
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil; nitrogen-fixer

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer; nitrogen-fixer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Abronia	*latifolia*		yellow sand verbena	native	dry to moist	no seed treatment; seeded	coastal sand dunes and coastal scrub
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds or container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Anaphalis	*margaritacea*		pearly everlasting	native	moist	no seed treatment; seeds	woods, roadsides, disturbance
Argemone	*munita*		prickly poppy	native	dry	no seed treatment; seeds	open areas, disturbance
Armeria	*maritima ssp. californica*		sea thrift	native	moist	no seed treatment; seeds and containers	coastal dune, sand, exposed grasslands
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds and containers	open to shady places in drainages
Aster	*chilensis*		Pacific aster	native	moist to wet	no seed treatment; seeds, containers	grasslands, salt marshes, disturbed places
Calystegia	*soldanella*		beach morning-glory	native	dry to moist	seed requires treatment; seeds, containers	rhizomatous; sandy seashores, coastal strand
Camassia	*quamash ssp. quamash*		camas	native	wet	seed requires treatment; containers	damp forests, wet meadows, streamsides
Camissonia	*cheiranthifolia*		beach evening primrose	native	dry to moist	no seed treatment; seed	sandy slopes, flats, coastal dunes
Carex	*nudata*		sedge	native	wet	no seed treatment; seeds, cuttings, containers	clumped, not rhizomatous; grass-like; streambeds
Carex	*obnupta*		slough sedge	native	moist to wet	no seed treatment; cuttings, containers	rhizomatous; grass-like; tolerates some salinity
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity
Carex	*spissa*		San Diego sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; waterways; tolerates serpentine
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Carex	*tumulicola*		Berkeley sedge	native	moist	no seed treatment; seeds, cuttings, containers	grass-like and rhizomatous; meadows, open woodlands
Eleocharis	*macrostachya*		spike rush	native	wet	seeds, plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Erigeron	*glaucus*		seaside daisy	native	dry	no seed treatment; low viability, seeds, containers	coastal bluffs, dunes, beaches; requires good drainage; low seed viability
Fragaria	*chiloensis*		beach strawberry	native	moist	no seed treatment; containers, sprigs	beaches, grassland
Fragaria	*vesca*		woodland strawberry	native	moist	no seed treatment; containers	partial shade in forests
Heuchera	*micrantha*		alumroot	native	moist to wet	no seed treatment; rooted stem cuttings, containers	moist rocky banks and cliffs; good ground cover
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus .	*patens*		spreading rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; densely clumping, marsh places
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Lathyrus	*littoralis*		beach pea	native	dry to moist	seed requires treatment; seeds, containers	open, coastal dune areas; sandy substrates; nitrogen-fixer
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lotus	*corniculatus*		bird's-foot trefoil	exotic	moist	fresh seeds--no treatment, stored seeds-treatment; seed	Introduced exotic; requires good drainage and is a good stabilizer; tolerates shade and acidic substrates, nitrogen-fixer
Lotus	*junceus*		lotus	native	dry	no seed treatment; seeds	coastal strand and chaparral, sometimes on serpentine; requires good drainage and full sun, nitrogen-fixer

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Monardella	*villosa*		coyote mint	native	dry	no seed treatment; vegetatively from rooted side shoots; seeds, containers	dry, rocky or gravelly places in oak woodland, chaparral, and montane forest; full sun to part shade
Oenothera	*elata ssp. hookeri*		California evening primrose	native	moist to wet	no seed treatment; seeds	moist places in coastal strand, sandy bluffs, to slightly inland; full sun; heavy seeder, good stabilizer
Oxalis	*oregana*		redwood sorrel	native	moist	no seed treatment; rhizome divisions; containers	moist conifer forests; shade; good groundcover
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase viability); seed, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils
Potentilla	*anserina ssp. pacifica*		Pacific silverweed	native	wet	seed requires treatment; division of stolons; seed, containers	wetlands; good stabilizer; tolerates somewhat alkaline soils
Salicornia	*virginica*		pickleweed	native	moist to wet	no seed treatment; containers	salt marshes near high tide elevations, alkaline flats; good stabilizer
Salvia	*spathacea*		pitcher sage	native	dry	no seed treatment; seeds. containers	chaparral, coastal sage scrub, oak woodland; shade-sun; tolerates clay and serpentine soils
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Sedum	*spathulifolium*		creeping stonecrop	native	dry to moist	containers	outcrops in forest communities, often in shade; requires good drainage
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds, containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Sisyrinchium	*californicum*		yellow-eyed grass	native	moist to wet	no seed treatment; rhizome divisions; seeds, containers	grass-like; moist, sunny places near coast
Tanacetum	*camphoratum*	*T. douglasii*	dune tansy	native	dry	no seed treatment, germination may be poor; seeds or divisions	good coastal groundcover, sandy soils, full sun
Trillium	*ovatum*		trillium	native	moist	seed requires treatment; seed, containers	redwood and mixed evergreen forest, shade and good drainage required, avoid heavy clay or sandy soils
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
Ambrosia	*chamissonis*		beach-bur	native	dry to moist	no seed treatment; seeds	sandy soils of beaches and dunes
Artemisia	*pycnocephala*		coastal sagewort	native	dry to moist	no seed treatment; seeds, containers	coastal dune, rocky or sandy soils
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral
Berberis	*nervosa*		barberry	native	moist	seed requires treatment; containers	coniferous forest
Ceanothus	*gloriosus var. gloriosus*		Pt. Reyes ceanothus	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; some varieties tolerate very sandy soils; prostrate; coastal bluffs, nitrogen-fixer; closed-cone-pine forest
Ceanothus	*griseus*		Carmel ceanothus	native	dry	seed requires treatment; seeds, containers	requires good drainage; tolerates full sun; prostrate--provides good groundcover; coastal scrub; closed-cone-pine forest; nitrogen-fixer
Ceanothus	*thrysiflorus*		blue blossom	native	dry	seed requires treatment; seeds, containers	requires good drainage; prostrate to erect; provides good groundcover and good stabilization; can tolerate some shade on south-facing slopes; wooded slopes and canyons; nitrogen-fixer

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Epilobium	*canum*	*Zauschneria californica*	California fuchsia	native	dry	no seed treatment; seeds, containers	dry slopes and ridges; different varieties; requires full sun and good drainage; spreads from underground stems; provides showy groundcover and is a good stabilizer
Ericameria	*ericoides*	*Haplopappus ericoides*	coast goldenbush	native	dry	no seed treatment; seeds, containers	dunes and inland sandy soils; requires full sun and good drainage
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Eriogonum	*latifolium*		coast buckwheat	native	dry to moist	no seed treatment; seeds, containers	requires full sun and good drainage; does best near the coast in very sandy soils
Eriogonum	*parvifolium*		coast buckwheat	native	dry	no seed treatment; seeds, containers	dunes, seabluffs; requires full sun and good drainage; does best near the coast in very sandy soils
Eriophyllum	*conferiflorum*		golden yarrow	native	dry	no seed treatment (treatment increases viability); seeds, containers	many dry habitats
Eriophyllum	*lanatum*		woolly sunflower	native	dry to moist	no seed treatment; seeds, containers	many varieties in many habitats
Frankenia	*salina*		alkali-heath	native	moist to wet	no seed treatment; containers	mat-forming in salt marshes, alkali flats; good ground cover
Gutierrezia	*californica*		snakeweed	native	dry to moist	no seed treatment; containers	grasslands, slopes, outcrops, sometimes on serpentine
Isocoma	*menziesii*	*Haplopappus venetus*	goldenbush	native	dry to moist	no seed treatment; seeds, containers	sandy soils; three varieties
Keckiella	*corymbosa*		redwood bush penstemon	native	dry	no seed treatment; seeds, containers	rocky slopes in coniferous or hardwood forests; requires good drainage
Lepechinia	*calycina*		pitcher sage	native	dry	seed requires treatment; seeds, containers	rocky slopes, chaparral, woodland; requires good drainage

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Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Lessingia	*filaginifolia*	*Corethrogyne f.*	California-aster	native	moist		highly variable; coastal scrub, oak woodlands, grasslands
Lonicera	*hispidula var. vacillans*		Californica honeysuckle	native	moist	seed requires treatment; cuttings; containers	along streams and on slopes in coniferous and foothill woodlands; requires shade; good ground cover; tolerates clay soils
Lupinus	*variicolor*		varicolored lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	meadows, coastal terraces and beaches, nitrogen-fixer
Mimulus	*aurantiacus*	*Diplacus, Mimulus longiflorus*	sticky monkeyflower	native	dry	no seed treatment; seeds or containers	consists of many different varieties; requires good drainage; requires full sun near coast, yet tolerates some shade inland
Polygonum	*paronychia*		dune knotweed	native	dry	seed requires treatment; containers	coastal dunes and scrub; requires good drainage; full sun-part shade; good groundcover
Senecio	*flaccidus*	*S. douglasii*	bush groundsel	native	dry	no seed treatment; seeds, containers	dry, rocky, or sandy sites; full sun, drought tolerant
Symphoricarpos	*mollis*		creeping snowberry	native	moist	seed requires treatment, cuttings or divisions; containers	dry, part-shady conditions in woods; good slope cover
Whipplea	*modesta*		yerba de selva	native	dry to moist	no seed treatment; containers	well-drained slopes in coniferous forest; prefers shade; forms a trailing, deciduous groundcover
shrub, vine							
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
shrub							
Acer	*circinatum*		vine maple	native	moist to wet	seed requires treatment; container	shaded streambanks
Adenostoma	*fasciculatum*		chamise	native	dry	fresh seeds require no treatment; seeds, containers	dry slopes, chaparral
Aesculus	*californicus*		buckeye	native	dry to moist	no seed treatment; seeds, containers	dry slopes, canyons, near streams

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Arctostaphylos	*glauca*		bigberry manzanita	native	dry	seed requires treatment; containers	rocky slopes, chaparral, woodland
Arctostaphylos	*manzanita*		common manzanita	native	dry	seed requires treatment; containers	rocky soils, chaparral, woodland, forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment
Artemisia	*californica*		California sagebrush	native	dry		coastal scrub, chaparral, foothills; requires full sun; provides good groundcover
Atriplex	*lentiformis ssp. lentiformis*		quailbush	native	dry	no seed treatment; seeds, containers	requires full sun and good drainage; alkaline and saline tolerant
Baccharis	*pilularis*	*B. p. var. consanguinea*	coyote bush	native	dry to moist	no seed treatment; seed, containers	coastal bluffs to woodlands, sometimes on serpentine; requires good drainage; provides good groundcover and good stabilization; some varieties are serpentine tolerant
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Ceanothus	*cuneatus*		buckbrush	native	dry	seed requires treatment; containers	many varieties, variable, prostrate to subshrub to shrub; some serpentine tolerance; requires good drainage; widespread, nitrogen-fixer
Ceanothus	*integerrimus*		deer brush	native	dry	seed requires treatment; containers	dry slopes, ridges; highly variable; disturbed roadsides, nitrogen-fixer
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; seeds require dormancy treatment; nitrogen-fixer; occurs in many habitats
Cercocarpus	*betuloides*		mountain mahogany	native	dry	no seed treatment; containers	chaparral, pine/oak woodland, coniferous forest; many varieties
Coreopsis	*gigantea*		giant coreopsis	native	moist	no seed treatment; containers	shrubby hillsides, coastal dunes, seabluffs; requires good drainage

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Cornus	*sericea ssp. sericea*	*Cornus stolonifera*	red osier dogwood	native	moist	seed requires treatment; stem cuttings, containers	many moist habitats; rooting stems
Corylus	*cornuta var. californica*		California hazelnut	native	moist	seed requires treatment; containers	riparian; shady places in many habitats
Dendromecon	*rigida*		bush poppy	native	dry	seed requires treatment; rooted stem cuttings, containers	dry slopes and washes, recent burns; requires good drainage
Encelia	*californica*		California brittlebush	native	dry	no seed treatment; germination may be poor, seed, container	coastal scrub; good stabilizer
Eriodictyon	*californicum*		yerba santa	native	dry to moist	seed requires treatment; seeds, containers	open areas, slopes, fields, roadsides, woodland, chaparral; invasive after disturbance; requires good drainage
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Garrya	*elliptica*		silktassel	native	dry to moist	seed requires treatment; containers	seacliffs, sand dunes, chaparral, foothill-pine woodland
Garrya	*fremontii*		mountain silktassel	native	dry to moist	seed requires treatment; containers	chaparral, foothill woodland, montane forest
Gaultheria	*shallon*		salal	native	moist	no seed treatment; containers	moist forest margins; tolerates acid soil; good ground cover
Heteromeles	*arbutifolia*		toyon	native	dry to moist	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	chaparral, oak woodland, mixed-evergreen forest; requires full sun and good drainage
Holodiscus	*discolor*		oceanspray	native	moist	seed requires treatment; containers	moist woodland edges, rocky slopes
Isomeris	*arborea*		bladder pod	native	dry to moist	no seed treatment; seeds, containers	coastal bluffs, hills, desert washes, flats; requires full sun and good drainage
Lonicera	*involucrata*		twinberry	native	moist to wet	seed requires treatment; cuttings; containers	moist places, such as riparian areas; sun to part shade
Lotus	*scoparius*		deerweed	native	dry	pods requires treatment, seeds do not; seeds, containers	requires full sun and good drainage; is a good stabilizer and provides good groundcover, nitrogen-fixer

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lupinus	*albifrons*		silver lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	many different varieties; generally requires good drainage and full sun; does well on very dry sites, nitrogen-fixer
Lupinus	*arboreus*		yellow bush lupine	native	moist	fresh seeds--no treatment, stored seeds-treatment; seeds	requires full sun and good drainage; tolerates sandy soils; is a good stabilizer; invasive exotic to Klamath Region, nitrogen-fixer
Malacothamnus	*fasciculatus*		chaparral bush mallow	native	dry	seed requires treatment; containers	coastal sage scrub and chaparral; full sun to part shade
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade
Prunus	*illicifolia*		hollyleaf cherry	native	dry	fresh seeds-no treatment, stored seeds-treatment; seeds, containers	slopes and canyons of shrubland and woodland; requires good drainage, sun to part shade; attracts beneficial insects
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Quercus	*berberidifolia*	*Q. dumosa misapplied*	scrub oak	native	dry to moist	seed requires treatment if stored; acorns, containers	dry slopes in chaparral; requires good drainage and full sun; some ecotypes acid-tolerant
Rhamnus	*californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	requires good drainage, tolerates partial shade; riparian species in the south; subspecies occidentalis is serpentine tolerant
Rhamnus	*californica ssp. californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	hillsides and ravines in chaparral, woodland, forest, and coastal sage scrub; does not tolerate serpentine soils; requires good drainage; host to beneficial insects

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Rhamnus	*crocea*		spiny redberry	native	dry	seeds require no treatment; containers	dry washes in coastal sage scrub, chaparral, and woodlands; requires good drainage
Rhamnus	*ilicifolia*	*R. crocea ssp. I.*	hollyleaf redberry	native	dry	fresh seeds require no treatment; containers	chaparral, montane forests, good on dry banks
Rhamnus	*tomentella ssp. tomentella*	*R. californica ssp. t.*	hoary coffeeberry	native	dry	fresh seeds require no treatment; containers	chaparral and woodlands; requires good drainage and sun
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Ribes	*malvaceum*		chaparral currant	native	dry to moist	seed requires treatment; containers	dry hills of Coast Ranges; requires good drainage; sun on coast and part shade inland
Ribes	*sanguineum*		red flowering currant	native	moist	seed requires treatment; tip cuttings; containers	moist, shaded places in forests of Coast Ranges; requires good drainage
Rosa	*californica*		California wild rose	native	moist	seed requires treatment; containers	riparian; prefers shade in the interior, sun on coast or at high elevations
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rubus	*leucodermis*		blackcap raspberry	native	moist	seed requires treatment; cuttings, root divisions; containers	hillslopes, canyon flats, and steambanks in montane areas
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salvia	*leucophylla*		purple sage	native	dry	no seed treatment; seeds, containers	requires good drainage and full sun; good groundcover and good stabilizer; attracts butterflies

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salvia	*mellifera*		black sage	native	dry	no seed treatment required; seeds, containers	coastal sage scrub, chaparral; requires good drainage and full sun; good groundcover and stabilizer; tolerates many soils types
tree							
Acer	*macrophyllum*		big-leaf maple	native	moist to wet	seed requires treatment; container	riparian, streambanks, canyons
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands
Alnus	*rhombifloia*		white alder	native	moist	no seed treatment, but low viability; cuttings, containers	riparian; rivers and streams, nitrogen-fixer
Alnus	*rubra*	*A. oregona*	red alder	native	wet	no seed treatment, but low viability; cuttings, containers	riparian; invades disturbed streamsides, nitrogen-fixer
Arbutus	*menziesii*		madrone	native	dry to moist	seed requires treatment; container	coniferous and oak forests
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Cornus	*nuttallii*		mountain dogwood	native	moist	seed requires treatment; containers	various woodlands and forest; requires shade
Cupressus	*macrocarpa*		Monterey cypress	native	dry to moist	no seed treatment; low seed viability, containers	closed cone-pine-cypress forest; native to Monterey Penn., but widely planted in cultivation
Fraxinus	*dipetala*		California ash	native	moist	seed requires treatment; containers	riparian, canyons, slopes, chaparral, oak/pine woodland
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Myrica	*californica*		wax myrtle	native	moist	seed requires treatment; cuttings; containers	moist, rich soil in shade or sun; canyons and moist slopes in redwood and closed cone pine forests, coastal dunes and scrub
Pinus	*attenuata*		knobcone pine	native	dry	seed requires treatment; containers	barren, rocky soils (often serpentine) in closed-cone pine forest and chaparral; tolerates fire; requires good drainage and full sun
Pinus	*contorta*		lodgepole pine	native	moist	fresh seeds-no treatment, stored seeds-treatment; containers	coastal to subalpine forest; many soil types; tolerates fire

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*ponderosa*		ponderosa pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; grows on many soil types
Pinus	*sabiniana*		foothill pine, gray pine	native	dry	seed requires treatment; containers	dry slopes and ridges in foothill woodland, chaparral, infertile soils in mixed conifer and hardwood forests; requires good drainage and full sun
Platanus	*racemosa*		sycamore	native	moist	seed requires treatment; containers	riparian areas and alluvial floodplains; requires good drainage and full sun; tolerates heat, wind, and moist soils; prefers sandy loam
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Pseudotsuga	*menziesii var. menziesii*		Douglas-fir	native	moist	seed requires treatment (no treatment may be satisfactory)	mixed evergreen and mixed conifer forests; sun to part shade
Quercus	*agrifolia*		coast live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	valleys and slopes in mixed evergreen forest and woodland; requires full sun and good drainage
Quercus	*chrysolepis*		canyon live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	canyons, shaded slopes, chaparral, mixed evergreen forest, woodland; full sun to part shade; tolerates wide range of soil types, including rocky substrates, heavy clay, and serpentine
Quercus	*kelloggii*		black oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes, valleys, woodland, coniferous forest; fire-related; requires good drainage, sun to part shade
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding

Appendix A5	CENTRAL WESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Sequoia	*sempervirens*		coast redwood	native	moist	no seed treatment, germination rate averages 10%; cuttings; containers	coastal fog belt; wide spreading shallow root system; mulch heavily
Umbellularia	*californica*		California bay	native	dry to moist	seed requires treatment; untreated fresh seed yields slow germination; containers	riparian canyons (tree); chaparral (shrub); shade to sun; loam, sandy loam, or clay soils, tolerates serpentine; releases terpenes that inhibit weeds

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Bromus	*laevipes ssp. rubens*	*B. rubens*	red brome	exotic	dry	no seed treatment; seeds	robust, highly invasive especially in deserts, very drought tolerant, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*occidentalis*	*Stipa o.*	needlegrass	native	dry	no seed treatment; seeds, containers	open dry sites, sagebrush scrub, coniferous forest, alpine
Achnatherum	*speciosum*	*Stipa s.*	desert needlegrass	native	dry	no seed treatment; seeds, containers	rocky slopes, canyons, washes, or sandy areas of sagebrush scrub; requires good drainage and full sun; good stabilizer
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Aristida	*purpurea var. parishii*		Parish three-awn	native	dry	no seed treatment; seeds	dry slopes, chaparral, shrubland

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Bouteloua	*curtipendula*		side-oats grama	native	dry	stored seeds--no treatment; seeds, containers	sandy to rocky drainages, scrub, woodland
Bouteloua	*gracilis*		blue grama	native	dry	stored seeds--no treatment; seeds, containers	desert scrub, woodland, pine forest
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader
Bromus	*inermis ssp. inermis*		smooth brome	exotic	moist	no seed treatment; seed	rhizomatous; meadows, ditches, fields
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Danthonia	*californica*		oatgrass	native	moist	no seed treatment; seeds, containers	moist, open sites, meadows, forests
Deschampsia	*caespitosa ssp. caespitosa*		tufted hairgrass	native	moist to wet	no seed treatment; seeds), containers	meadows, streambanks, coastal marsh, forests, alpine; densely-tufted bunchgrass, excellent stabilizer; can withstand summer drought if saturated in spring
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*elymoides ssp. elymoides*	*Sitanion hystrix*	squirreltail	native	dry	no seed treatment; seeds, containers	bunchgrass; best in open, very dry situations and on poor soils, serpentine tolerant
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Elymus	*trachycaulus ssp. trachycaulus*	*Agropyron subsecundus*	big squirreltail	native	dry to moist	no seed treatment; seeds, containers	dry to moist, open areas, forest, woodland
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Festuca	*rubra*		red fescue	native	dry	no seed treatment; seeds, containers	varieties available (beware of less adaptive non-natives); sand dunes, grassland, subalpine forest; loosely tufted groundcover
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Koeleria	*macrantha*		junegrass	native	dry to moist	no seed treatment; seeds, containers	open sites, clay to rocky soils, shrubland, woodland, coniferous forest, alpine
Leymus	*condensatus*	*Elymus condensatus*	giant wild-rye	native	dry	seed requires treatment; seeds, containers	dry slopes, open woodland; requires good drainage, provides good groundcover
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Melica	*imperfecta*		Coast Range oniongrass	native	dry	no seed treatment; seeds or containers	loosely tufted bunchgrass, tolerant of serpentine
Muhlenbergia	*rigens*		deergrass	native	moist	no seed treatment; vegetatively by plant divisions; containers	along streams, meadow edges, hillside seeps, ditches, and roads; dry, damp, or moist conditions; full sun to part shade; withstands short duration flooding; tolerates flooding; forms dense clumps
Nassella	*cernua*	*Stipa c.*	nodding needlegrass	native	dry	no seed treatment; seed, containers	bunchgrass; dry slopes in chaparral, grassland, and juniper woodland; best on well-drained sandy loam, but tolerates rocky soil; full sun to part shade; does well on poor soils; good stabilizer
Nassella	*lepida*	*Stipa l.*	foothill needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; dry slopes, chaparral, open woods; full sun to part shade; good bank stabilizer
Nassella	*pulchra*	*Stipa p.*	purple needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; adapted to clay soils, tolerant of summer drought and heat, tolerant of serpentine, tolerant of poor soils
Pleuraphis	*rigida*	*Hilaria r.*	big galleta	native	dry	seeds	dry, open, sandy to rocky slopes, flats, and washes, sand dunes, scrub, woodland; requires full sun and good drainage; good forage, stabilizer

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
Spartina	*foliosa*		cordgrass	native	wet	seed treatment required; rhizome divisions; containers, plugs	dense, monospecific stands in tidal zone of salt marshes
Sporobolus	*airoides*		alkali sacaton	native	moist	seed requires treatment; seed	perennial bunchgrass with extensive fibrous root system; best on deep, moist, fine-textured soils but also grows on coarser soils on dry sites; tolerates saline and sodic soils
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Lasthenia	*glabrata*		goldfields	native	wet		saline places, vernal pools; requires full sun
Layia	*platyglossa*		tidy-tips	native	dry to moist		many habitats; requires full sun
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Plantago	*ovata*	*P. insularis*	desert plantain	native	dry	seed requires treatment; seeds	sandy or gravelly soils in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and coastal strand; full sun to part shade; good colonizer

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salvia	*columbariae*		chia	native	dry	seed germination often improved with treatment; seeds or containers	dry, open, often disturbed places in scrub and chaparral; requires full sun and good drainage; gravelly slopes and sandy soils
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil, nitrogen-fixer
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer, nitrogen-fixer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
herb, perennial							
Abronia	*latifolia*		yellow sand verbena	native	dry to moist	no seed treatment; seeded	coastal sand dunes and coastal scrub
Abronia	*villosa*		desert sand verbena	native	dry	no seed treatment; seeded	sandy places in creosote-bush or coastal-sage scrub
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds or container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Argemone	*munita*		prickly poppy	native	dry	no seed treatment; seeds	open areas, disturbance
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds and containers	open to shady places in drainages
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Aster	*chilensis*		Pacific aster	native	moist to wet	no seed treatment; seeds, containers	grasslands, salt marshes, disturbed places
Calystegia	*soldanella*		beach morning-glory	native	dry to moist	seed requires treatment; seeds, containers	rhizomatous; sandy seashores, coastal strand
Camissonia	*cheiranthifolia*		beach evening primrose	native	dry to moist	no seed treatment; seed	sandy slopes, flats, coastal dunes
Carex	*barbarae*		Santa Barbara sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; seasonally wet places; invasive
Carex	*nudata*		sedge	native	wet	no seed treatment; seeds, cuttings, containers	clumped, not rhizomatous; grass-like; streambeds
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Carex	*spissa*		San Diego sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; waterways; tolerates serpentine
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection
Castilleja	*linariifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	dry plains, rocky slopes, sagebrush shrubland, pinyon/juniper woodland
Eleocharis	*macrostachya*		spike rush	native	wet	seeds, plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Epilobium	*angustifolium ssp. circumvagum*		fireweed	native	dry to moist	no seed treatment; seeds, containers	open places, roadsides; can be invasive, especially after fire
Erigeron	*glaucus*		seaside daisy	native	dry	no seed treatment; low seed viability, seeds, containers	coastal bluffs, dunes, beaches; requires good drainage
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Oenothera	*elata ssp. hookeri*		California evening primrose	native	moist to wet	no seed treatment; seeds	moist places in coastal strand, sandy bluffs, to slightly inland; full sun; heavy seeder, good stabilizer
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase germination); seed, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Potentilla	*anserina ssp. pacifica*		Pacific silverweed	native	wet	seed requires treatment; division of stolons; seed, containers	wetlands; good stabilizer; tolerates somewhat alkaline soils
Potentilla	*gracillis*		slender cinquefoil	native	moist	no seed treatment; seeds	mostly moist places in meadows and open forests; full sun
Romneya	*coulteri*		Coulter's matilija poppy	native	dry	seed requires treatment; best from root cuttings; containers	dry washes and canyons in coastal sage scrub and chaparral; requires good drainage and full sun; prefers sandy soils
Salicornia	*virginica*		pickleweed	native	moist to wet	no seed treatment; containers	salt marshes near high tide elevations, alkaline flats; good stabilizer
Salvia	*spathacea*		pitcher sage	native	dry	no seed treatment; seeds. containers	chaparral, coastal sage scrub, oak woodland; shade-sun; tolerates clay and serpentine soils
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins
Sedum	*spathulifolium*		creeping stonecrop	native	dry to moist	containers	outcrops in forest communities, often in shade; requires good drainage
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds or containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
Wyethia	*angustifolia*		narrowleaf mules ears	native	dry	seed treatment not necessary, but may help; seeds, containers	requires full sun and good drainage, grassland
shrub, subshrub							
Ambrosia	*chamissonis*		beach-bur	native	dry to moist	no seed treatment; seeds	sandy soils of beaches and dunes
Berberis	*aquifolium*		Oregon grape	native	moist	seed requires treatment; containers	coniferous forest, oak woodland, chaparral

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Ceanothus	*cordulatus*		mountain whitethorn	native	dry	seed requires treatment; containers	can be prostate; rocky ridges, open pine forests; requires good drainage, nitrogen-fixer
Coreopsis	*maritima*		sea dahlia	native	moist	no seed treatment; containers	seabluffs; large taproot
Epilobium	*canum*	*Zauschneria californica*	California fuchsia	native	dry	no seed treatment; seeds, containers	dry slopes and ridges; different varieties; requires full sun and good drainage; spreads from underground stems; provides showy groundcover and is a good stabilizer
Ericameria	*ericoides*	*Haplopappus ericoides*	coast goldenbush	native	dry	no seed treatment; seeds, containers	dunes and inland sandy soils; requires full sun and good drainage
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Eriogonum	*parvifolium*		coast buckwheat	native	dry	no seed treatment; seeds, containers	dunes, seabluffs; requires full sun and good drainage; does best near the coast in very sandy soils
Eriogonum	*umbellatum*		sulfur-flowered buckwheat	native	dry	no seed treatment (treatment increases germination); seeds, containers	many varieties; dry open, often rocky places; some varieties tolerate serpentine; is a good stabilizer
Eriophyllum	*conferiflorum*		golden yarrow	native	dry	no seed treatment (treatment increases germination); seeds, containers	many dry habitats
Eriophyllum	*lanatum*		woolly sunflower	native	dry to moist	no seed treatment; seeds, containers	many varieties in many habitats
Frankenia	*salina*		alkali-heath	native	moist to wet	no seed treatment; containers	mat-forming in salt marshes, alkali flats; good ground cover
Gutierrezia	*californica*		snakeweed	native	dry to moist	no seed treatment; containers	grasslands, slopes, outcrops, sometimes on serpentine
Hymenoclea	*salsola*		cheesebush	native	dry	no seed treatment; seeds, containers	dry flats, washes, fans, disturbed areas; varieties
Isocoma	*menziesii*	*Haplopappus venetus*	goldenbush	native	dry to moist	no seed treatment; seeds, containers	sandy soils; three varieties

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Keckiella	*antirrhinoides var. antirrhinoides*		bush snapdragon	native	dry	no seed treatment; seeds, containers	chaparral, oak forest; requires good drainage and full to partial sun
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Lessingia	*filaginifolia*	*Corethrogyne f.*	California-aster	native	moist		highly variable; coastal scrub, oak woodlands, grasslands
Lonicera	*hispidula var. vacillans*		Californica honeysuckle	native	moist	seed requires treatment; cuttings; containers	along streams and on slopes in coniferous and foothill woodlands; requires shade; good ground cover; tolerates clay soils
Mimulus	*aurantiacus*	*Diplacus, Mimulus longiflorus*	sticky monkeyflower	native	dry	no seed treatment; seeds or containers	consists of many different varieties; requires good drainage; requires full sun near coast, yet tolerates some shade inland
Salvia	*apiana*		white sage	native	dry	no seed treatment; seeds, containers	coastal sage scrub; requires good drainage and full sun; good groundcover and stabilizer; tolerates very dry sites; allelopathic through terpenes
Salvia	*leucophylla*		purple sage	native	dry	no seed treatment; seeds, containers	requires good drainage and full sun; good groundcover and good stabilizer; attracts butterflies
Salvia	*mellifera*		black sage	native	dry	no seed treatment required; seeds, containers	coastal sage scrub, chaparral; requires good drainage and full sun; good groundcover and stabilizer; tolerates many soils types
Salvia	*sonomensis*		creeping sage	native	dry	seed requires treatment; divisions; cuttings; containers	chaparral, oak woodland, and yellow pine forest; prostrate, mat-forming; requires good drainage, full sun, dry sites; provides a good groundcover; fire resistant if mowed and lightly irrigated; tolerates clay and serpentine soils
Senecio	*flaccidus*	*S. douglasii*	bush groundsel	native	dry	no seed treatment; seeds, containers	dry, rocky, or sandy sites; full sun, drought tolerant
Symphoricarpos	*mollis*		creeping snowberry	native	moist	seed requires treatment, cuttings or divisions; containers	dry, part-shady conditions in woods; good slope cover
Whipplea	*modesta*		yerba de selva	native	dry to moist	no seed treatment; containers	well-drained slopes in coniferous forest; prefers shade; forms a trailing, deciduous groundcover
shrub, vine							

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
Vitis	*girdiana*		desert wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; fast-growing; sprawling, climbing growth habit; sandy soil
shrub							
Adenostoma	*fasciculatum*		chamise	native	dry	fresh seeds require no treatment; seeds, containers	dry slopes, chaparral
Arctostaphylos	*glauca*		bigberry manzanita	native	dry	seed requires treatment; containers	rocky slopes, chaparral, woodland
Arctostaphylos	*patula*		greenleaf manzanita	native	dry	seed requires treatment; seeds, containers	shrublands, open coniferous forest
Arctostaphylos	*spp.*		manzanita	native	dry	seed requires treatment; containers	consists of many different species, subspecies and varieties; some are prostrate, others up to 15' tall; most require full sun and good drainage; seeds require dormancy treatment
Artemisia	*californica*		California sagebrush	native	dry		coastal scrub, chaparral, foothills; requires full sun; provides good groundcover
Baccharis	*emoryi*		Emory's baccharis	native	moist	no seed treatment; containers	riparian, sandy edges of rivers, washes, salt marshes
Baccharis	*pilularis*	*B. p. var. consanguinea*	coyote bush	native	dry to moist	no seed treatment; seed, containers	coastal bluffs to woodlands, sometimes on serpentine; requires good drainage; provides good groundcover and good stabilization; some varieties are serpentine tolerant
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Baccharis	*sarothoides*		broom baccharis	native	dry to moist	no seed treatment; seed, containers	gravelly and sandy roadsides, washes
Ceanothus	*cuneatus*		buckbrush	native	dry	seed requires treatment; containers	many varieties, variable, prostrate to subshrub to shrub; some serpentine tolerance; requires good drainage; widespread, nitrogen-fixer
Ceanothus	*integerrimus*		deer brush	native	dry	seed requires treatment; containers	dry slopes, ridges; highly variable; disturbed roadsides, nitrogen-fixer

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; nitrogen-fixer; occurs in many habitats
Cercocarpus	*ledifolius*		curl-leaf mountain mahogany	native	dry	seed requires treatment; containers	deep soils, rocky slopes; requires good drainage; pinyon/juniper, sagebrush scrub, open pine forest
Cercocarpus	*minutiflorus*	*C. montanus*	mountain mahogany	native	dry	seed requires treatment; containers	chaparral; requires good drainage and full sun
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related
Coreopsis	*gigantea*		giant coreopsis	native	moist	no seed treatment; containers	shrubby hillsides, coastal dunes, seabluffs; requires good drainage
Dendromecon	*rigida*		bush poppy	native	dry	seed requires treatment; rooted stem cuttings, containers	dry slopes and washes, recent burns; requires good drainage
Encelia	*californica*		California brittlebush	native	dry	no seed treatment; germination may be poor, seed, container	coastal scrub; good stabilizer
Encelia	*farinosa*		brittlebush	native	dry	no seed treatment; germination may be poor, seed, container	coastal scrub, stony desert hillsides; requires full sun and good drainage
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Garrya	*elliptica*		silktassel	native	dry to moist	seed requires treatment; containers	seacliffs, sand dunes, chaparral, foothill-pine woodland
Heteromeles	*arbutifolia*		toyon	native	dry to moist	fresh seeds--no treatment, stored seeds-treatment; seeds, containers	chaparral, oak woodland, mixed-evergreen forest; requires full sun and good drainage; seeds require special treatment
Holodiscus	*discolor*		oceanspray	native	moist	seed requires treatment; containers	moist woodland edges, rocky slopes
Holodiscus	*microphyllus*		rock spiraea	native	dry to moist	seed requires treatment; containers	rocky places, outcrops; a few varieties
Isomeris	*arborea*		bladder pod	native	dry to moist	no seed treatment; seeds, containers	coastal bluffs, hills, desert washes, flats; requires full sun and good drainage
Lotus	*scoparius*		deerweed	native	dry	pods require treatment, seeds do not; seeds, containers	requires full sun and good drainage; is a good stabilizer and provides good groundcover, nitrogen-fixer

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Lycium	*andersonii*		Anderson's box thorn	native	dry	no seed treatment; seeds or containers	gravelly or rocky slopes, washes
Lycium	*californicum*		desert thorn	native	dry	no seed treatment; containers	coastal bluffs and coastal sage scrub; requires good drainage and full sun; good stabilizer
Malacothamnus	*fasciculatus*		chaparral bush mallow	native	dry	seed requires treatment; containers	coastal sage scrub and chaparral; full sun to part shade
Malosma	*laurina*	*Rhus l.*	laurel sumac	native	dry	seed requires treatment; containers	slopes, canyons, chaparral; requires good drainage; resprouts after fire
Opuntia	*basilaris var. basilaris*		beavertail	native	dry	no seed treatment required; vegetatively from stem divisions; containers	desert, chaparral, pinyon-juniper woodland; requires full sun and good drainage
Physocarpus	*capitatus*		western ninebark	native	moist	seed requires treatment; easily propagated from cuttings, containers	prefers moist banks on north-facing slopes in coniferous forests; requires part shade; good groundcover in coastal region
Prunus	*emarginata*		bitter cherry	native	moist	seed requires treatment; containers	rocky ridges to moist slopes and canyons in chaparral and mixed evergreen and coniferous forests; requires good drainage and some shade
Prunus	*illicifolia*		hollyleaf cherry	native	dry	fresh seeds-no treatment, stored seeds-treatment; seeds, containers	slopes and canyons of shrubland and woodland; requires good drainage, sun to part shade; attracts beneficial insects
Prunus	*virginiana var. demissa*		western chokecherry	native	moist	seed requires treatment; containers	seasonally moist places near drainages and in foothills and mountain slopes; requires good drainage, sun to part shade; browsed by livestock and wildlife
Quercus	*berberidifolia*	*Q. dumosa misapplied*	scrub oak	native	dry to moist	seed requires treatment if stored; acorns, containers	dry slopes in chaparral; requires good drainage and full sun; some ecotypes acid-tolerant
Quercus	*dumosa*		Nuttall's scrub oak	native	dry	seed requires treatment if stored; acorns, containers	general on sandy soils near coast, sandstone, chaparral, coastal sage scrub; requires full sun and good drainage
Rhamnus	*californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	requires good drainage, tolerates partial shade; riparian species in the south; subspecies occidentalis is serpentine tolerant

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Rhamnus	*californica ssp. californica*		California coffeeberry	native	dry to moist	fresh seeds require no treatment; containers	hillsides and ravines in chaparral, woodland, forest, and coastal sage scrub; does not tolerate serpentine soils; requires good drainage; host to beneficial insects
Rhamnus	*crocea*		spiny redberry	native	dry	seeds require no treatment; containers	dry washes in coastal sage scrub, chaparral, and woodlands; requires good drainage
Rhamnus	*ilicifolia*	*R. crocea ssp. I.*	hollyleaf redberry	native	dry	fresh seeds require no treatment; containers	chaparral, montane forests, good on dry banks
Rhamnus	*tomentella ssp. tomentella*	*R. californica ssp. t.*	hoary coffeeberry	native	dry	fresh seeds require no treatment; containers	chaparral and woodlands; requires good drainage and sun
Rhus	*integrifolia*		lemonadeberry	native	dry	seed requires treatment; containers	north-facing slopes in canyons dominated by chaparral; requires good drainage; good for erosion control
Rhus	*ovata*		sugar bush	native	dry	seed requires treatment; containers	south-facing canyon slopes in chaparral; requires good drainage
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Rosa	*californica*		California wild rose	native	moist	seed requires treatment; containers	riparian; prefers shade in the interior, sun on coast or at high elevations
Rosa	*gymnocarpa*		wood rose	native	dry to moist	seed requires treatment; containers	forests and shrublands; requires good drainage, part shade, and coarse-textured soils
Rubus	*leucodermis*		blackcap raspberry	native	moist	seed requires treatment; cuttings, root divisions; containers	hillslopes, canyon flats, and steambanks in montane areas
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salvia	*clevelandii*		Cleveland sage	native	dry	no seed treatment; seeds, containers	chaparral, coastal sage scrub; requires good drainage and full sun

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salvia	*leucophylla*		white sage	native	dry	no seed treatment; seeds, containers	requires good drainage and full sun; good groundcover and good stabilizer; attracts butterflies
Salvia	*mellifera*		black sage	native	dry	no seed treatment required; seeds, containers	coastal sage scrub, chaparral; requires good drainage and full sun; good groundcover and stabilizer; tolerates many soils types
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
Styrax	*officinalis var. redivivus*	*S. o. var. californica*	snowdrop bush	native	dry	seed requires treatment; containers	full sun to light shade; dry places in chaparral and woodland; tolerates drought, heat, and rocky soils
Tetradymia	*canescens*		horsebrush	native	dry	seed or basal root sprouts; seed, containers	sandy and rocky soils in sagebrush scrub and pinyon/juniper woodland
Trichostema	*lanatum*		woolly bluecurls	native	dry	seed requires treatment, easily propagated from stem cuttings; containers	coastal scrub, chaparral; requires good drainage, full sun, and dry conditions
Yucca	*whipplei*		our Lord's candle	native	dry	no seed treatment; seeds or offsets, containers	full sun to light shade and good drainage; hardy to 10º F; fire retardant
tree							
Abies	*concolor*		white fir	native	moist	seed requires treatment; tubelings, supercell	mixed conifer to lower red-fir forests
Acer	*macrophyllum*		big-leaf maple	native	moist to wet	seed requires treatment; container	riparian, streambanks, canyons
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands
Alnus	*rhombifloia*		white alder	native	moist	no seed treatment, but low viability; cuttings, containers	riparian; rivers and streams, nitrogen-fixer
Arbutus	*menziesii*		madrone	native	dry to moist	seed requires treatment; container	coniferous and oak forests
Calocedrus	*decurrens*	*Libocedrus d.*	incense cedar	native	dry to moist	seed requires treatment; containers	fire tolerant; mixed evergreen to coniferous forests
Cornus	*nuttallii*		mountain dogwood	native	moist	seed requires treatment; containers	various woodlands and forest; requires shade
Fraxinus	*dipetala*		California ash	native	moist	seed requires treatment; containers	riparian, canyons, slopes, chaparral, oak/pine woodland
Fraxinus	*velutina*		ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Juglans	*californica var. californica*		So. California black walnut	native	moist	seed requires treatment; containers	riparian, slopes, canyons, valleys
Juniperus	*osteosperma*		Utah juniper	native	dry	seed requires treatment; containers	pinyon/juniper woodlands
Pinus	*attenuata*		knobcone pine	native	dry	seed requires treatment; containers	barren, rocky soils (often serpentine) in closed-cone pine forest and chaparral; tolerates fire; requires good drainage and full sun
Pinus	*contorta*		lodgepole pine	native	moist	fresh seeds-no treatment, stored seeds-treatment; containers	coastal to subalpine forest; many soil types; tolerates fire
Pinus	*jeffreyi*		Jeffrey pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; red fir and yellow pine forests; tolerates serpentine
Pinus	*lambertiana*		sugar pine	native	moist	seed requires treatment; cuttings possible; containers	mixed conifer and mixed evergreen forests; moist, steep, north- and east-facing slopes to more mesic south-facing slopes; requires good drainage; world's tallest pine
Pinus	*ponderosa*		ponderosa pine	native	dry to moist	fresh seeds-no treatment, stored seeds-treatment; containers	requires good drainage and full sun; grows on many soil types
Pinus	*sabiniana*		foothill pine, gray pine	native	dry	seed requires treatment; containers	dry slopes and ridges in foothill woodland, chaparral, infertile soils in mixed conifer and hardwood forests; requires good drainage and full sun
Platanus	*racemosa*		sycamore	native	moist	seed requires treatment; containers	riparian areas and alluvial floodplains; requires good drainage and full sun; tolerates heat, wind, and moist soils; prefers sandy loam
Populus	*balsamifera ssp. trichocarpa*		black cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valley; full sun
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Quercus	*agrifolia*		coast live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	valleys and slopes in mixed evergreen forest and woodland; requires full sun and good drainage
Quercus	*chrysolepis*		canyon live oak	native	dry to moist	seed requires treatment if stored; acorns, containers	canyons, shaded slopes, chaparral, mixed evergreen forest, woodland; full sun to part shade; tolerates wide range of soil types, including rocky substrates, heavy clay, and serpentine

Appendix A6	SOUTHWESTERN CALIFORNIA						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Quercus	*douglasii*		blue oak	native	dry	seed requires treatment if stored; acorns, containers	dry slopes in woodlands of interior foothills; requires full sun and good drainage
Quercus	*englemannii*		Engelmann oak	native	dry to moist	seed requires treatment if stored; acorns, containers	slopes, foothills, riparian, woodland; requires full sun and good drainage
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding
Quercus	*wislizenii*		interior live oak	native	dry	seed requires treatment if stored; acorns, containers	interior canyons, slopes, and valleys; requires full sun and good drainage
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
Hordeum	*depressum*		low barley	native	moist to wet	no seed treatment; seeds, containers	loosely clumped, tolerates alkaline soils; can withstand summer drought if saturated in spring
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Lolium	*multiflorum*		annual ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields; robust, tolerates clay soils, highly invasive, impacts vernal pools, outcompetes natives
Vulpia	*microstachys*	*Festuca m.*	six weeks fescue	native	dry to moist	seed	fast growing cover crop, matures early, not overly aggressive, open disturbed sandy soils
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Agropyron	*desertorum*		crested wheatgrass	exotic	dry to moist	no seed treatment; seeds	disturbed areas, roadsides; robust invader, outcompetes natives
Agrostis	*exarata*		spike bentgrass	native	moist to wet	no seed treatment; seeds	open woodland, disturbed areas; excellent for stabilizing disturbed area
Alopecurus	*aequalis*		short-awn foxtail	exotic	wet	no seed treatment; seeds	best use for perennially moist to wet area (channel protection)
Bouteloua	*curtipendula*		side-oats grama	native	dry	stored seeds--no treatment; seeds, containers	sandy to rocky drainages, scrub, woodland
Bromus	*carinatus*		California brome	native	moist to wet	no seed treatment; seed, containers	bunchgrass; provides good groundcover, good invader
Dactylis	*glomerata*		orchard grass	exotic	dry to moist	no seed treatment; seeds	bunchgrass, adapted to most areas in CA, outcompetes natives; disturbed sites
Deschampsia	*elongata*		slender hairgrass	native	moist to wet	no seed treatment; seeds, plugs, containers	wet sites, meadow, lakeshores, shaded slopes

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*glaucus*		blue wildrye	native	moist to wet	no seed treatment; seeds	good stabilizer; tolerates full sun; many subspecies; open areas, chaparral, woodland, forest; requires good drainage
Festuca	*arundicacea*		tall fescue	exotic	moist	no seed treatment; seeds	disturbed places, robust invader, outcompetes natives
Hordeum	*brachyantherum ssp. brachyantherum*		meadow barley	native	moist to wet	no seed treatment; seed, containers	forms clumps; tolerant of alkaline soil, infertile soil, and compacted sites
Hordeum	*brachyantherum var. californicum*	*H. californicum*	California barley	native	dry to moist	no seed treatment; seeds, containers	meadows, pasture, streambanks; forms clumps; one variety is very short (<8 inches tall), tolerates alkaline and infertile soil
Lolium	*perenne*		perennial ryegrass	exotic	dry to moist	no seed treatment; seeds	disturbed places, fields, lawns; robust, highly invasive, outcompetes natives
Muhlenbergia	*rigens*		deergrass	native	moist	no seed treatment; vegetatively by plant divisions; containers	along streams, meadow edges, hillside seeps, ditches, and roads; dry, damp, or moist conditions; full sun to part shade; withstands short duration flooding; tolerates flooding; forms dense clumps
Nassella	*pulchra*	*Stipa p.*	purple needlegrass	native	dry	no seed treatment; seeds, containers	bunchgrass; adapted to clay soils, tolerant of summer drought and heat, tolerant of serpentine, tolerant of poor soils
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Puccinellia	*nuttalliana*		Nuttall's alkali-grass	native	moist to wet	seeds	saline meadows and flats; good stabilizer and valuable forage grass
Sporobolus	*airoides*		alkali sacaton	native	moist	seed requires treatment; seed	perennial bunchgrass with extensive fibrous root system; best on deep, moist, fine-textured soils but also grows on coarser soils on dry sites; tolerates saline and sodic soils

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Lasthenia	*glabrata*		goldfields	native	wet		saline places, vernal pools; requires full sun
Layia	*platyglossa*		tidy-tips	native	dry to moist		many habitats; requires full sun
Lotus	*micranthus*		lotus	native	dry to moist	no seed treatment; seeds	widespread in open or disturbed areas; good colonizer, nitrogen-fixer
Lupinus	*bicolor*		pigmy-leaved lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	requires full sun and good drainage; is a good stabilizer; nitrogen-fixer
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Trifolium	*hirtum*		rose clover	exotic	dry to moist	no seed treatment; seeds	disturbed areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
Trifolium	*incarnatum*		crimson clover	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives; tolerates slightly acid soil; nitrogen-fixer
Trifolium	*willdenovii*	*T. tridentatum*	tomcat clover	native	dry to moist	seed	spring moist, heavy soils; good colonizer; nitrogen-fixer
Vicia	*villosa*		wollypod vetch	exotic	dry to moist	no seed treatment; seeds	roadsides, fields, waste areas; robust invader, adapted to most areas in CA, outcompetes natives; nitrogen-fixer
herb, perennial							
Achillea	*millefolium*		yarrow	native	dry to wet	no seed treatment; seeds, container	ubiquitous, highly variable species with many ecotypes; good stabilizer, invades on disturbed sites
Artemisia	*douglasiana*		mugwort	native	moist to wet	no seed treatment; seeds, containers	open to shady places in drainages

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Carex	*barbarae*		Santa Barbara sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; seasonally wet places; invasive
Carex	*nebrascensis*		Nebraska sedge	native	wet	no seed treatment; seeds, cuttings, containers	grass-like; meadows and swamps
Carex	*nudata*		sedge	native	wet	no seed treatment; seeds, cuttings, containers	clumped, not rhizomatous; grass-like; streambeds
Carex	*praegracilis*		sedge	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; tolerates alkalinity
Carex	*spp.*		sedges	native	moist to wet	no seed treatment; seeds, cuttings, containers	grass-like; some form clumps, others are rhizomatous and would be good for use in channel protection.
Eleocharis	*macrostachya*		spike rush	native	wet	seeds, plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Juncus	*balticus*		baltic rush	native	dry to moist	no seed treatment; seeds, containers, plugs	grass-like; many habitats; highly variable and invasive
Juncus	*effusus*		Pacific rush	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; four distinct varieties, var. brunneus invasive
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lupinus	*polyphyllus*		blue lupine	native	wet	fresh seeds--no treatment, stored seeds-treatment; seeds	moist areas to bogs; requires full sun and good drainage, nitrogen-fixer
Penstemon	*heterophyllus*		foothill penstemon	native	dry	no seed treatment (treatment may increase viability); seed, containers	grassland, chaparral, and forest openings; tolerates poor, rocky soils
Salicornia	*virginica*		pickleweed	native	moist to wet	no seed treatment; containers	salt marshes near high tide elevations, alkaline flats; good stabilizer
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Scirpus	*microcarpus*		small-fruited bulrush	native	wet	rhizome divisions; containers, plugs	marshes, wet meadows, streambanks, pond margins

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Sidalcea	*malvaeflora*		checker mallow	native	dry to moist	seed requires treatment; seeds or divisions, containers	open, relatively dry places in forest, scrub, prairies, and grasslands
Sisyrinchium	*bellum*		blue-eyed grass	native	moist	seed over 3-6 years requires treatment; clump division; seeds or containers	grass-like; open, sunny, generally moist grassy areas, woodlands
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
shrub, subshrub							
Ericameria	*linearifolia*	*Haplopappus l.*	narrowleaf goldenbush	native	dry	no seed treatment; seeds, containers	dry slopes, valleys
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Frankenia	*salina*		alkali-heath	native	moist to wet	no seed treatment; containers	mat-forming in salt marshes, alkali flats; good ground cover
Gutierrezia	*californica*		snakeweed	native	dry to moist	no seed treatment; containers	grasslands, slopes, outcrops, sometimes on serpentine
Isocoma	*menziesii*	*Haplopappus venetus*	goldenbush	native	dry to moist	no seed treatment; seeds, containers	sandy soils; three varieties
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Lessingia	*filaginifolia*	*Corethrogyne f.*	California-aster	native	moist		highly variable; coastal scrub, oak woodlands, grasslands
Senecio	*flaccidus*	*S. douglasii*	bush groundsel	native	dry	no seed treatment; seeds, containers	dry, rocky, or sandy sites; full sun, drought tolerant
shrub, vine							
Clematis	*ligusticifolia*		virgin's bower	native	moist to wet	no seed treatment; containers	riparian, streams, wet places; requires shade
Vitis	*californica*		California wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; sprawling, climbing growth habit; tolerates most soil textures; sun or access to sun; fast-grower, forms groundcover if no support
shrub							
Aesculus	*californicus*		buckeye	native	dry to moist	no seed treatment; seeds and containers	dry slopes, canyons, near streams

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Atriplex	*lentiformis ssp. lentiformis*		quailbush	native	dry	no seed treatment; seeds, containers	requires full sun and good drainage; alkaline and saline tolerant
Atriplex	*polycarpa*		alkali saltbush	native	dry	no seed treatment; seeds	alkaline flats, dry lakes
Atriplex	*spinifera*		spiny saltbush	native	dry	seed	saline soils, flats, dry lakes
Baccharis	*pilularis*	*B. p. var. consanguinea*	coyote bush	native	dry to moist	no seed treatment; seed, containers	coastal bluffs to woodlands, sometimes on serpentine; requires good drainage; provides good groundcover and good stabilization; some varieties are serpentine tolerant
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Cephalanthus	*occidentalis var. californicus*		buttonwillow	native	moist to wet	no seed treatment; cuttings, containers	riparian, lake, streamedges, drainages; can withstand reservoir drawdown
Cercis	*occidentalis*		redbud	native	dry	seed requires treatment; seeds, containers	requires full sun and good drainage; is a good stabilizer; seeds require dormancy treatment; nitrogen-fixer; occurs in many habitats
Fremontodendron	*californicum ssp. californicum*		flannelbush	native	dry	seed requires treatment; containers	chaparral, oak/pine woodland, rocky ridges
Rhus	*trilobata*		skunkbush	native	dry	seed requires treatment; containers	slopes and washes in chaparral, coastal sage scrub, and woodland; drought tolerant; sun to part shade; good stabilizer
Rosa	*californica*		California wild rose	native	moist	seed requires treatment; containers	riparian; prefers shade in the interior, sun on coast or at high elevations
Rubus	*ursinus*	*R. vitifolius*	California blackberry	native	moist	seed requires treatment; cuttings, root divisions; containers	riparian areas, woodland clearings; low-growing, trailing or climbing; tolerates wide range of soil textures but requires adequate moisture
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Sambucus	*mexicana*	*S. caerulea*	blue elderberry	native	moist to wet	seed requires treatment; stem cuttings, containers	moist, well-drained sites, especially in riparian areas; sun to shade; attracts wildlife
tree							
Acer	*negundo var. californicum*		box elder	native	moist	seed requires treatment; container	riparian, streamsides and bottomlands

Appendix A7	GREAT CENTRAL VALLEY						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Fraxinus	*latifolia*		Oregon ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Juglans	*californica var. hindsii*		Hinds walnut	native	moist	seed requires treatment; containers	riparian, canyons, valleys
Platanus	*racemosa*		sycamore	native	moist	seed requires treatment; containers	riparian areas and alluvial floodplains; requires good drainage and full sun; tolerates heat, wind, and moist soils; prefers sandy loam
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Quercus	*lobata*		valley oak	native	moist	seed requires treatment if stored; acorns, containers	riparian, slopes, valleys, savannah; requires full sun, good drainage, and deep, rich soils; tolerates seasonal flooding
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Bromus	*hordeaceus*	*B. mollis*	blando brome	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, out-competes natives
Hordeum	*jubatum*		foxtail barley	native	dry to moist	no seed treatment; seeds, containers	most habitats
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*hymenoides*	*Oryzopsis hymenoides*	Indian ricegrass	native	dry	fresh seeds require no treatment; seeds and containers	dry, sandy soil, desert shrub, sagebrush scrub, pinyon/juniper
Achnatherum	*speciosum*	*Stipa s.*	desert needlegrass	native	dry	no seed treatment; seeds, containers	rocky slopes, canyons, washes, or sandy areas of sagebrush scrub; requires good drainage and full sun; good stabilizer
Aristida	*purpurea var. parishii*		Parish three-awn	native	dry	no seed treatment; seeds	dry slopes, chaparral, shrubland
Bouteloua	*curtipendula*		side-oats grama	native	dry	stored seeds--no treatment; seeds, containers	sandy to rocky drainage, scrub, woodland
Bouteloua	*eriopoda*		black grama	native	dry	stored seeds--no treatment; seeds, containers	sandy to rocky slopes, flats and drainage, scrub, woodland
Bouteloua	*gracilis*		blue grama	native	dry	stored seeds--no treatment; seeds, containers	desert scrub, woodland, pine forest
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomitous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Elymus	*elymoides ssp. elymoides*	*Sitanion hystrix*	squirreltail	native	dry	no seed treatment; seeds, containers	bunchgrass; best in open, very dry situations and on poor soils, serpentine tolerant
Hesperostipa	*comata*	*Stipa c.*	needle and thread	native	dry	no seed treatment; seeds, containers	grassland, sagebrush shrubland, pinyon/juniper woodland
Muhlenbergia	*porteri*		muhly	native	dry	no seed treatment; vegetatively by plant divisions; containers	among boulders or shrubs, rocky slopes, cliffs; forms dense clumps; most often within shrub canopy; must be protected from grazing
Pleuraphis	*jamesii*	*Hilaria j.*	galleta grass	native	dry to moist	seeds	dry, sandy to rocky slopes, flats, scrub, woodland; full sun and good drainage; good stabilizer
Pleuraphis	*rigida*	*Hilaria r.*	big galleta	native	dry	seeds	dry, open, sandy to rocky slopes, flats, and washes, sand dunes, scrub, woodland; requires full sun and good drainage; good forage stabilizer

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Sporobolus	*airoides*		alkali sacaton	native	moist	seed requires treatment; seed	perennial bunchgrass with extensive fibrous root system; best on deep, moist, fine-textured soils but also grows on coarser soils on dry sites; tolerates saline and sodic soils
Sporobolus	*contractus*		spike dropseed	native	dry to moist	seed requires treatment, seed	large perennial bunchgrass; rocky to sandy washes, slopes, shrubland; drought tolerant
Sporobolus	*cryptandrus*		sand dropseed	native	dry to moist	seed requires treatment, seed	perennial bunchgrass; rocky to sandy washes, slopes, shrubland, woodland; drought tolerant, thrives on sandy sites, establishes easily, good for erosion control
herb, annual							
Castilleja	*exserta*	*Orthocarpus purpurascens*	purple owl's clover	native	dry to moist	no seed treatment; seeds, containers	various subspecies and highly variable; open fields, grasslands, coastal bluffs and dunes
Eschscholzia	*californica*		California poppy	native	dry to moist	no seed treatment; seed	grass, open areas; disturbance related
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Lasthenia	*californica*		dwarf goldfields	native	dry to moist		highly variable, many habitats, requires full sun
Lasthenia	*glabrata*		goldfields	native	wet		saline places, vernal pools; requires full sun
Nemophila	*menziesii*		baby blue-eyes	native	moist	no seed treatment; seeds	meadows, fields, woodlands, grasslands, desert washes; sun; many soils types, does especially well on loamy clay
Plantago	*ovata*	*P. insularis*	desert plantain	native	dry	seed requires treatment; seeds	sandy or gravelly soils in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and coastal strand; full sun to part shade; good colonizer
Salvia	*columbariae*		chia	native	dry	seed germination often improved with treatment; seeds or containers	dry, open, often disturbed places in scrub and chaparral; requires full sun and good drainage; gravelly slopes and sandy soils
herb, perennial							
Abronia	*villosa*		desert sand verbena	native	dry	no seed treatment; seeded	sandy places in creosote-bush or coastal-sage scrub
Argemone	*munita*		prickly poppy	native	dry	no seed treatment; seeds	open areas, disturbance
Artemisia	*ludoviciana*		silver wormwood	native	dry	no seed treatment; seeds, containers	dry, sandy to rocky soils
Astragalus	*lentiginosus*		freckled milkvetch	native	dry	no seed treatment; seeds, containers	highly variable, many distinct varieties; variable habitats; nitrogen-fixer

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Baileya	*multiradiata var. multiradiata*		desert marigold	native	dry	no seed treatment; seed, containers	desert roadsides, flats, washes, hillsides
Castilleja	*angustifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	sagebrush scrub, pinyon/juniper woodland
Castilleja	*linariifolia*		Indian paintbrush	native	dry	no seed treatment; seeds, containers	dry plains, rocky slopes, sagebrush shrubland, pinyon/juniper woodland
Eleocharis	*macrostachya*		spike rush	native	wet	seeds/plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Lupinus	*argenteus*		mountain lupine	native	dry	fresh seeds--no treatment, stored seeds-treatment; seeds	montane forest and sagebrush scrub, nitrogen-fixer
Penstemon	*palmeri var. palmeri*		Palmer penstemon	native	dry	seed requires treatment; seeds	open, exposed areas such as rocky hillsides, road banks, gravel pits, or gravelly washes in creosote bush scrub to juniper/pinyon woodland; does well on limestone soils
Salvia	*dorrii*		desert sage	native	dry	seed requires treatment; seeds, containers	dry, rocky places; grows well on sand, volcanic rock, & decomposed granite; requires good drainage
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Sphaeralcea	*ambigua*		desert mallow	native	dry	no seed treatment; seeds, containers	desert scrub, requires good drainage and full sun
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
shrub, subshrub							
Acamptopappus	*sphaerocephlus*		goldenhead	native	dry	containers	gravelly or rocky soils in deserts to juniper woodlands
Ambrosia	*dumosa*		burweed	native	dry	no seed treatment; seeds	creosote bush scrub
Brickellia	*incana*		brickellbush	native	dry	no seed treatment; containers	sandy washes, flats
Ericameria	*linearifolia*	*Haplopappus l.*	narrowleaf goldenbush	native	dry	no seed treatment; seeds, containers	dry slopes, valleys
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Frankenia	*salina*		alkali-heath	native	moist to wet	no seed treatment; containers	mat-forming in salt marshes, alkali flats; good ground cover
Hymenoclea	*salsola*		cheesebush	native	dry	no seed treatment; seeds, containers	dry flats, washes, fans, disturbed areas; varieties
Krascheninnikovia	*lanata*	*Ceratoidea l., Eurotia l.*	winter fat	native	dry	no seed treatment; seeds, containers	rocky to clay soils, flats, gentle slopes; requires good drainage and full sun
Lepidium	*fremontii*		peppergrass	native	dry	stored seeds--no treatment; seeds, containers	sandy washes, barren knolls, gravelly soils, rocky slopes, ridges; requires well-drained soils
Leptodactylon	*pungens*		prickly-phlox	native	dry	no seed treatment; seeds, containers	open, rocky areas in montane, subalpine forests, and alpine fell-fields; requires good drainage and full sun
Senecio	*flaccidus*	*S. douglasii*	bush groundsel	native	dry	no seed treatment; seeds, containers	dry, rocky, or sandy sites; full sun, drought tolerant
Xylorhiza	*tortifolia var. tortifolia*	*Machaeranthera t.*	Mojave aster	native	dry	no seed treatment; seeds, containers	desert slopes and canyons; dry rocky slopes; requires good drainage and full sun
Yucca	*baccata*		banana yucca	native	dry	no seed treatment; offsets, cuttings, seeds; containers	full sun to light shade, heat resistant, requires good drainage, typically on dry slopes
Yucca	*schidigera*		Mojave yucca	native	dry	no seed treatment; offsets, cuttings, seeds; containers	full sun to light shade, heat resistant, requires good drainage, typically on dry slopes
shrub, vine							
Vitis	*girdiana*		desert wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; fast-growing; sprawling, climbing growth habit; sandy soil
shrub							
Acacia	*greggii*		catclaw	native	dry to moist	no seed treatment; seeds, containers	sandy to gravelly soils, washes and streambanks; nitrogen-fixer
Artemisia	*cana ssp. bolanderi*		silver sagebrush	native	dry to moist	seeds	gravelly soils, meadows, streambanks
Artemisia	*tridentata*		sagebrush	native	dry	fresh seeds--no treatment, stored seeds--treatment; containers	dry soils in many scrubs, shrublands, and woodlands
Atriplex	*canescens*		four-wing saltbush	native	dry	stored seeds--no treatment; seeds, containers	dry slopes, flats, and shrublands; good stabilizer and invader in desert areas
Atriplex	*confertifolia*		shadscale	native	dry	stored seeds--no treatment; containers	alkaline flats, shrubland, pinyon/juniper
Atriplex	*hymenolytra*		desert holly	native	dry	stored seeds--no treatment; containers	shrublands, washes

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Atriplex	*lentiformis ssp. lentiformis*		quailbush	native	dry	no seed treatment; seeds, containers	requires full sun and good drainage; alkaline and saline tolerant
Atriplex	*lentiformis ssp. torreyi*	*A. torreyi*	big saltbush	native	moist	no seed treatment; seeds, containers	alkaline flats, dry lakes, washes
Atriplex	*polycarpa*		alkali saltbush	native	dry	no seed treatment; seeds	alkaline flats, dry lakes
Atriplex	*spinifera*		spiny saltbush	native	dry	seed	saline soils, flats, dry lakes
Baccharis	*emoryi*		Emory's baccharis	native	moist	no seed treatment; containers	riparian, sandy edges of rivers, washes, salt marshes
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Baccharis	*sarothoides*		broom baccharis	native	dry to moist	no seed treatment; seed, containers	gravelly and sandy roadsides, washes
Chilopsis	*lnearis ssp. arcuata*		desert willow	native	dry	no seed treatment; containers	sandy washes; full sun and good drainage
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related
Chrysothamnus	*paniculatus*		black-stem rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	common in gravelly washes
Chrysothamnus	*viscidiflorus*		yellow rabbitbrush	native	dry	no seed treatment; seeds, containers	many subspecies; sagebrush, pinyon/juniper woodland
Coleogyne	*ramosissima*		blackbrush	native	dry	seed requires treatment; containers	dry, open slopes, creosote-bush scrub, pinyon/juniper woodland; on soils with hardpan (caliche)
Encelia	*farinosa*		brittlebush	native	dry	no seed treatment; germination may be poor, seed, container	coastal scrub, stony desert hillsides; requires full sun and good drainage
Encelia	*virginesis*		brittlebush	native	dry	no seed treatment; germination poor, container	desert flats, rocky slopes, roadsides; requires full sun and good drainage
Ephedra	*nevadensis*		Mormon tea	native	dry	seed requires treatment; containers	creosote-bush scrub, joshua-tree woodland; requires full sun and good drainage
Ephedra	*viridis*		green Mormon tea	native	dry	seed requires treatment; containers	sagebrush scrub, creosote-bush scrub, pinyon/juniper woodland
Ericameria	*cooperi var. cooperi*	*Haplopappus c.*	goldenbush	native	dry	no seed treatment; seeds, containers	creosote-bush scrub, Joshua-tree woodland
Ericameria	*laricifolia*	*Haplopappus l.*	turpentine-brush	native	dry	no seed treatment; seeds, containers	rocky canyons; creosote-bush scrub, pinyon/juniper woodlands
Ericameria	*linearifolia*	*Haplopappus l.*	interior goldenbush	native	dry	no seed treatment; seeds, containers	dry slopes and valleys
Fallugia	*paradoxa*		Apache plume	native	dry	no seed treatment; container	dry, rocky slopes in pinyon/juniper woodland
Grayia	*spinosa*		spiny hopsage	native	dry	no seed treatment (treatment increases viability); containers	sandy to gravelly soils, shrubland, pinyon/juniper woodland

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Gutierrezia	*microcephala*		sticky snakeweed	native	dry	no seed treatment; seeds, containers	sandy to gravelly soils, shrubland, pinyon/juniper woodland
Holodiscus	*microphyllus*		rock spiraea	native	dry to moist	seed requires treatment; containers	rocky places, outcrops; a few varieties
Hymenoclea	*salsola*		cheesebush	native	dry	no seed treatment; seeds, containers	dry flats, washes, fans, disturbed areas; many varieties
Isomeris	*arborea*		bladder pod	native	dry to moist	no seed treatment; seeds, containers	coastal bluffs, hills, desert washes, flats; requires full sun and good drainage
Larrea	*tridentata*		creosote bush	native	dry	seed requires treatment; seeds, containers	desert scrub; requires good drainage and full sun; clonal
Lycium	*andersonii*		Anderson's box thorn	native	dry	no seed treatment; containers	gravelly or rocky slopes, washes
Lycium	*cooperi*		Cooper's box thorn	native	dry	no seed treatment; containers	sandy, gravelly or rocky slopes, washes
Opuntia	*basilaris var. basilaris*		beavertail	native	dry	no seed treatment required; vegetatively from stem divisions; containers	desert, chaparral, pinyon-juniper woodland; requires full sun and good drainage
Penstemon	*pseudospectabilis*		desert beard-tongue	native	dry	seed requires treatment; containers	gravelly or rocky desert washes and canyon floors in creosote bush scrub and juniper/pinyon woodland; prefers sandy or well-drained soils and full sun
Prunus	*andersonii*		desert peach	native	dry	seed requires treatment; containers	rocky slopes and flats in sagebrush steppe and pinyon-juniper woodland; requires good drainage and full sun
Prunus	*fasciculata*		desert almond	native	dry	seed requires treatment; containers	slopes, canyons, and washes in creosote bush scrub and Joshua tree woodland; requires good drainage and full sun
Purshia	*mexicana var. stansburyana*	*Cowania m. var. s.*	Stansbury cliffrose	native	dry	seed requires treatment; containers	dry sites such as mesas and foothills in Joshua tree or pinyon-juniper woodland; requires good drainage and full sun; prefers rocky, gravelly soils
Purshia	*tridentata*		antelope bitterbrush	native	dry	seed requires treatment; containers	dry Joshua tree or pinyon-juniper woodland; requires good drainage and full sun; tolerates rocky, but not saline soils
Salazaria	*mexicana*		bladder sage	native	dry	no seed treatment; seed or rhizome divisions, or containers	sandy to gravelly slopes, washes, creosote bush scrub, josuha tree woodland; requires good drainage and full sun
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer
Salvia	*dorrii*		desert sage	native	dry	no seed treatment; seeds, containers	dry, rocky places; grows well on sand, volcanic rock, & decomposed granite; requires good drainage
Sarcobatus	*vermiculatus*		greasewood	native	dry to moist	seed requires treatment; seeds, containers	alkaline soils, dry lakes, washes, shrubland; deep taproot
Senna	*armata*	*Cassia a.*	spiny senna	native	dry	containers	sandy or gravelly washes

Appendix A8	MOJAVE DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Stenotus	*acaulis*	*Haplopappus a.*	stenotus	native	dry	container	dry, rocky, open shrubland; mat-forming
tree							
Fraxinus	*velutina*		ash	native	moist	seed requires treatment; containers	riparian, canyons, streambanks, woodland
Juniperus	*osteosperma*		Utah juniper	native	dry	seed requires treatment; containers	pinyon/juniper woodlands
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Prosopis	*glandulosa var. torreyana*		mesquite	native	moist to wet	fresh, undried seeds--no treatment; stored seeds--treatment; containers	riparian; alkali flats, washes, bottomlands, sandy alluvial flats; easily grown and good stabilizer
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Yucca	*brevifolia*		Joshua tree	native	dry	no seed treatment; usually grown from offsets or cuttings; does not tolerate bare root transplanting; containers	requires hot climate, full sun, and good drainage; periodic deep soaking in summer until established; hardy to 0º F; slow growing

Appendix A9	SONORAN DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
grass, annual							
Avena	*spp.*		oats	exotic	dry to moist	no seed treatment; seeds	disturbed sites; invasive
Vulpia	*myuros*		zorro fescue	exotic	dry to moist	no seed treatment; seeds	robust invader, adapted to most areas in CA, outcompetes natives
grass, perennial							
Achnatherum	*hymenoides*	*Oryzopsis hymenoides*	Indian ricegrass	native	dry	fresh seeds require no treatment; seeds and containers	dry, sandy soil, desert shrub, sagebrsuh scrub, pinyon/juniper
Achnatherum	*speciosum*	*Stipa s.*	desert needlegrass	native	dry	no seed treatment; seeds or containers	rocky slopes, canyons, washes, or sandy areas of sagebrush scrub; requires good drainage and full sun; good stabilizer
Aristida	*purpurea var. parishii*		Parish three-awn	native	dry	no seed treatment; seeds	dry slopes, chaparral, shrubland
Distichlis	*stricta*		saltgrass	native	moist to wet	no seed treatment; low seed viability, plugs	salt marshes, good groundcover and good stabilizer, highly rhizomatous; tolerates saline and alkaline water and soil; can withstand summer drought if saturated in spring, often grown from rhizomes, requires full sun
Pleuraphis	*rigida*	*Hilaria r.*	big galleta	native	dry	seeds	dry, open, sandy to rocky slopes, flats, and washes, sand dunes, scrub, woodland; requires full sun and good drainage; good forage, stabilizer
Poa	*secunda ssp. secunda*	*P. sandbergii, P. scabrella*	bluegrass	native	dry to moist	no seed treatment; seeds	many areas, including plains, dry woods, rocky slopes, foothills, grassy slopes ridgetops, open timber; grows well in rich clay loam but also thrives in shallow, rocky, or sandy soils; sun-part shade; grows on neutral, alkaline, and saline soils; forage
Sporobolus	*airoides*		alkali sacaton	native	moist	seed requires treatment; seed	perennial bunchgrass with extensive fibrous root system; best on deep, moist, fine-textured soils but also grows on coarser soils on dry sites; tolerates saline and sodic soils
Sporobolus	*cryptandrus*		sand dropseed	native	dry to moist	seed requires treatment, seed	rocky to sandy washes, slopes, shrubland, woodland; drought tolerant, thrives on sandy sites, establishes easily, good for erosion control
herb, annual							

Appendix A9	SONORAN DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Helianthus	*annus*		common sunflower	native	dry to moist	no seed treatment; seeds	disturbed areas, shrublands and many other habitats; requires full sun
Plantago	*ovata*	*P. insularis*	desert plantain	native	dry	seed requires treatment; seeds	sandy or gravelly soils in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and coastal strand; full sun to part shade; good colonizer
Salvia	*columbariae*		chia	native	dry	seed germination often improved with treatment; seeds or containers	dry, open, often disturbed places in scrub and chaparral; requires full sun and good drainage; gravelly slopes and sandy soils
herb, perennial							
Abronia	*villosa*		desert sand verbena	native	dry	no seed treatment; seeded	sandy places in creosote-bush or coastal-sage scrub
Artemisia	*ludoviciana*		silver wormwood	native	dry		dry, sandy to rocky soils
Eleocharis	*macrostachya*		spike rush	native	wet	seeds/plugs	grass-like; marshes, pond margins, vernal pools, ditches; good stabilizer in wet areas; grown from rhizomes
Juncus	*spp*		rush species	native	moist to wet	no seed treatment; seeds, containers, plugs	grass-like; some species are clump forming other are more rhizomatous; excellent stabilizer for swales and riparian areas; some are best grown from rhizomes or plugs
Linum	*lewisii*		blue flax	native	dry	no seed treatment; seeds	dry open ridges and slopes; requires full sun
Scirpus	*acutus var. occidentalis*		common tule	native	moist to wet	seed requires treatment, rhizome divisions; containers, plugs	marshes, lakes, streambanks; forms large colonies; tolerant of alkalinity and summer drawdown
Sphaeralcea	*ambigua*		desert mallow	native	dry	no seed treatment; seeds, containers	desert scrub, requires good drainage and full sun
Typha	*latifolia*		broadleaf cattail	native	wet	seed requires treatment; vegetatively by dividing rhizomes; containers, plugs	forms dense monocultures in freshwater marshes, good colonizer
shrub, subshrub							
Acomptopappus	*sphaerocephlus*		goldenhead	native	dry	containers	gravelly or rocky soils in deserts to juniper woodlands
Ambrosia	*dumosa*		burweed	native	dry	no seed treatment; seeds	creosote bush scrub

Appendix A9	SONORAN DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Brickellia	*incana*		brickellbush	native	dry	no seed treatment; containers	sandy washes, flats
Ericameria	*linearifolia*	*Haplopappus l.*	narrowleaf goldenbush	native	dry	no seed treatment; seeds, containers	dry slopes, valleys
Eriogonum	*fasciculatum*		California buckwheat	native	dry	no seed treatment; seeds, containers	consists of many different varieties; dry slopes, washes, canyons in scrub, disturbed areas; requires full sun and good drainage; is a good stabilizer and provides good groundcover
Lepidium	*fremontii*		peppergrass	native	dry	stored seeds--no treatment; seeds, containers	sandy washes, barren knolls, gravelly soils, rocky slopes, ridges; requires well-drained soils
Senecio	*flaccidus*	*S. douglasii*	bush groundsel	native	dry	no seed treatment; seeds, containers	dry, rocky, or sandy sites; full sun, drought tolerant
shrub, vine							
Vitis	*girdiana*		desert wild grape	native	moist	no seed treatment, but may improve germination of stored seeds; containers	riparian; fast-growing; sprawling, climbing growth habit; sandy soil
shrub							
Atriplex	*canescens*		four-wing saltbush	native	dry	stored seeds--no treatment; seeds, containers	dry slopes, flats, and shrublands; good stabilizer and invader in desert areas
Atriplex	*hymenolytra*		desert holly	native	dry	stored seeds--no treatment; containers	shrublands, washes
Atriplex	*lentiformis ssp. lentiformis*		quailbush	native	dry	no seed treatment; seeds, containers	requires full sun and good drainage; alkaline and saline tolerant
Atriplex	*polycarpa*		alkali saltbush	native	dry	no seed treatment; seeds	alkaline flats, dry lakes
Baccharis	*emoryi*		Emory's baccharis	native	moist	no seed treatment; containers	riparian, sandy edges of rivers, washes, salt marshes
Baccharis	*salicifolia*		mule fat	native	moist to wet	no seed treatment; cuttings, containers	riparian, canyon bottoms, streamsides, irrigation ditches
Baccharis	*sarothoides*		broom baccharis	native	dry to moist	no seed treatment; seed, containers	gravelly and sandy roadsides, washes
Chilopsis	*lnearis ssp. arcuata*		desert willow	native	dry	no seed treatment; containers	sandy washes; full sun and good drainage
Chrysothamnus	*nauseosus*		rubber rabbitbrush	native	dry to moist	no seed treatment; seeds, containers	numerous subspecies; many habitats; requires good drainage; some subspecies disturbance related

Appendix A9	SONORAN DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Coleogyne	*ramosissima*		blackbrush	native	dry	seed requires treatment; containers	dry, open slopes, creosote-bush scrub, pinyon/juniper woodland; on soils with hardpan (caliche)
Encelia	*farinosa*		brittlebush	native	dry	no seed treatment; germination may be poor, seed, containers	coastal scrub, stony desert hillsides; requires full sun and good drainage
Ephedra	*nevadensis*		mormon tea	native	dry	seed requires treatment; containers	creosote-bush scrub, Joshua tree woodland; requires full sun and good drainage
Fallugia	*paradoxa*		Apache plume	native	dry	no seed treatment; container	dry, rocky slopes in pinyon/juniper woodland
Grayia	*spinosa*		spiny hopsage	native	dry	no seed treatment (treatment increases viability); containers	sandy to gravelly soils, shrubland, pinyon/juniper woodland
Isomeris	*arborea*		bladder pod	native	dry to moist	no seed treatment; seeds, containers	coastal bluffs, hills, desert washes, flats; requires full sun and good drainage
Larrea	*tridentata*		creosote bush	native	dry	seed requires treatment; seeds, containers	desert scrub; requires good drainage and full sun; clonal
Lycium	*andersonii*		Anderson's box thorn	native	dry	no seed treatment; seeds or containers	gravelly or rocky slopes, washes
Opuntia	*basilaris var. basilaris*		beavertail	native	dry	no seed treatment required; vegetatively from stem divisions; containers	desert, chaparral, pinyon-juniper woodland; requires full sun and good drainage
Penstemon	*pseudospectabilis*		desert beard-tongue	native	dry	seed requires treatment; containers	gravelly or rocky desert washes and canyon floors in creosote bush scrub and juniper/pinyon woodland; prefers sandy or well-drained soils and full sun
Prunus	*fasciculata*		desert almond	native	dry	seed requires treatment; containers	slopes, canyons, and washes in creosote bush scrub and Joshua tree woodland; requires good drainage and full sun
Salazaria	*mexicana*		bladder sage	native	dry	no seed treatment; seed or rhizome divisions, or containers	sandy to gravelly slopes, washes, creosote bush scrub, Joshua tree woodland; requires good drainage and full sun
Salix	*exigua*		sandbar willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian, excellent colonizer and streambank stabilizer

Appendix A9	SONORAN DESERT						
Genus	**Species**	**Synonym**	**Common Name**	**Origin**	**Tolerance**	**Propagation**	**Comments**
Salvia	*dorrii*		desert sage	native	dry	no seed treatment; seeds, containers	dry, rocky places; grows well on sand, volcanic rock, & decomposed granite; requires good drainage
Senna	*armata*	*Cassia a.*	spiny senna	native	dry	containers	sandy or gravelly washes
tree							
Cercidium	*floridum ssp. floridum*		blue palo verde	native	dry	no seed treatment; containers	desert washes, nitrogen-fixer
Populus	*fremontii ssp. fremontii*		Fremont cottonwood	native	moist to wet	no seed treatment; best from stem cuttings	riparian and alluvial valleys, full sun; good stabilizer; cultivars used for phytoremediation
Salix	*goodingii*		Goodding's black willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian
Salix	*laevigata*		red willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization
Salix	*lasiolepis*		arroyo willow	native	moist to wet	no seed treatment; best propagated from stem cuttings	riparian; good for streambank stabilization

APPENDIX B
SAMPLE MONITORING FORMS

EROSION AND SEDIMENTATION MONITORING
(Note location of problem areas on a site map)

NAME____ **DATE**__________________
SITE #___________________________ **PHASE**___________________________________
DESCRIPTION OF LOCATION____

INLET PROTECTION

_____ Installed _______ Operating correctly _______ Needs repair

Comments:____

CHECK DAMS and WATER BARS

_____ Installed _______ Operating correctly _______ Additional dams/bars
_____ Undermined _______ Short circuited _______ Blown out
_____ Remove sediment

Comments:____

DRAINAGE SWALES

_____ Installed _______ Operating correctly _______ Undermined
_____ Short circuited _____ Blown out _______ Remove sediment

Comments:____

SURFACE MULCH (NATIVE OR STRAW)

_____ Type _______ Operating correctly _______ Additional mulch req'd

Comments:____

SLOPE INSTABILITY

_____ Pre-existing _______Evidence of sliding/failure cracks

Comments:____

SURFACE EROSION

______ Sheet ______ Piled debris ______ Rilling

______ Gully (2-6") ______ Large Gully (6"+)

Comments: ____

____

QUALITATIVE DESCRIPTIONS OF SOIL SURFACE STATUS (Table A-1)

______ Size of area ______ Score

Comments: ____

____

TABLE A-1
QUALITATIVE DESCRIPTIONS OF SOIL SURFACE STATUS

CLASS 1: No soil loss or erosion; topsoil layer intact, well-dispersed accumulation of litter from past year's growth plus smaller amounts of older litter.

CLASS 2: Soil movement slight and difficult to recognize; small deposits of soil in form of fans or cones at end of small gullies or fills, or as accumulations back of plant crowns or behind litter, litter not well dispersed or no accumulation from past year's growth obvious.

CLASS 3: Soil movement or loss more noticeable; topsoil loss evident, with some plants on pedestals or in hummocks; rill marks evident, poorly dispersed litter and bare spots not protected by litter.

CLASS 4: Soil movement and loss readily recognizable; topsoil remnants with vertical sides and exposed plant roots, roots frequently exposed, litter in relatively small amounts and washed into erosion protected patches.

CLASS 5: Advanced erosion; active gullies, steep sidewalls on active gullies; well-developed erosion pavement on gravelly soils, litter mostly washed away.

Stoddart et al. 1975

VEGETATION MONITORING, SAMPLE DATA SHEET

Name ____________________________ Date ___________ Site # ___________

Plot Size ____________ Plot Number ______________ Photo # ______________

Treatment Received (i.e., type of mulch, resoiled?) ______________________________

____

____

____

Plot Data: Total Plant Cover ___________ Percent Bare Ground ________________

Percent Litter ______________ Percent Exposed Gravel or Cobble ________

____

____

Taxa:

Shrubs	Percent Cover	Number (density)	Height/Vigor

Herbs	Percent Cover	Number (density)	Height/Vigor

Notes:

APPENDIX C
SAMPLE OUTLINE FOR A REHABILITATION PLAN*

I. EXECUTIVE SUMMARY
- A. Impacted versus Created Vegetation & Habitat Type
- B. Project Goals
- C. Summary Schedule

II. DESCRIPTION OF PROJECT AND AFFECTED AREA
- A. Location
- B. Brief Project Summary and Schedule
- C. Parties Responsible for Project
- D. Required Permits
- E. Environmental Setting
  1. Climate, Aspect
  2. Configuration and Topography
  3. Hydrology (Surface and Groundwater), Water Quality
  4. Geology/Geomorphology
  5. Soils, Testing and Descriptions
  6. Vegetation/Habitat Maps and Descriptions
  7. Sensitive/Target Species and Habitats
- F. Summary of Project Impacts
- G. Project Constraints

III. ENVIRONMENTAL DESCRIPTION OF AREA(S) TO BE REVEGETATED
- A. Location and Size
- B. Current and Proposed Uses
- C. Owner,Land Manager, other Involved Parties
- D. Required Permits
- E. Existing Environmental Settings
  1. Climate, Aspect
  2. Level of Existing Disturbance
  3. Configuration and Topography
  4. Hydrology (Surface and Groundwater), Water Quality
  5. Geology/Geomorphology
  6. Soils, Testing and Descriptions
  7. Vegetation/Habitat Maps and Descriptions
  8. Sensitive/Target Species and Habitats
- F. Site Access and Accessibility
- G. Site Constraints (e.g., zoning, current uses)
- H. Rehabilitation Potential

IV. GOALS
- A. Rehabilitation Goals
- B. Drainage & Hydrology
- C. Slope Stability
- D. Erosion and Sediment Control
- E. Sensitive/Target Species and Habitats
- F. Relationship to Mitigation Measures
- G. Time Lapse

V. IMPLEMENTATION PLAN AND SPECIFICATIONS
- A. Responsible Parties
- B. Schedule
- C. Ingress/Egress
- D. Land Shaping, Grading, and Drainage
- E. Protections for Extant Vegetation
- F. Soil/Substrate/Growth Media
  1. Testing
  2. Salvaging, Stockpiling, Replacing
  3. Decompaction
  4. Amending
  5. Mulching (inclusive of native mulches)
  6. Fertilizing
  7. Weed Eradication
  8. Slope Protection, and Erosion and Sediment Control
- G. Plant Materials
  1. Species Selections, Plant materials, and Quantities
  2. Propagule source (e.g., commercial, custom collect)
  3. Plant Handling
  4. Planting Rates, Densities, Spacing
  5. Planting Methods (Details)
  6. Planting Locations
  7. Plant Protection (e.g., screens, weedstop, wire cages)
  8. Planting and Seeding Schedule
  9. Irrigation, Frequency, Duration, Source and Water Quality
  10. Inspections During Implementation, Frequency

VI. SITE MAINTENANCE
- A. Schedule of Activities (during implementation phase)
- B. Description of Activities
  1. Weed Control
  2. Fertilizing
  3. Irrigation/Supplemental Watering
  4. Replanting
  5. Erosion Control
  6. Control of Anthropogenic Effects (e.g., fencing, signing)
- C. Evaluation and Reporting of Maintenance Activities
- D. Description of Long-term Maintenance

VII. PERFORMANCE STANDARDS
- A. Derivation of Performance Standards
  1. Externally Derived (e.g., industry standards, local ordinances)
  2. Internally Derived (e.g., developed on a project-specific basis)
- B. Standards by Project Element (e.g., trees, shrubs, community, ecosystem, soils), both Interim and Final
  1. Qualitative Standards (e.g., photo reference points, visual/aesthetic)
  2. Quantitative Standards (e.g., plant cover, plant density, species-richness, eco system functions, erosion, soils, weeds
  3. Reference Site(s) or other Controls

VIII. MONITORING
   A. Description of Monitoring Methods
   B. Discussion of methods for Analyzing Results
   C. Reporting Format and Contents
   D. Sample Data Sheets (or in Appendix)

IX. REMEDIAL MEASURES
   A. Proposed Remedial Measures (in tabular form)
   B. Criteria for Implementation
   C. Effects on Monitoring and Performance Standards

X. BONDING/ASSURNANCE
   A. Responsible Party
   B. Detailed Cost Estimate
   C. Payees
   D. Schedule of Release

APPENDICES

1. Sample Monitoring Forms
2. Baseline Data
3. As-Built Conditions (Appended at a later date)

*Originally compiled in 1992 by Gail Newton, Ann Howald, and Deborah Hillyard for SERCAL workshop

APPENDIX D
REHABILITATION PLAN EVALUATION CHECKLIST*

The following checklist was designed to help planners who review rehabilitation plans.

Project Title:	
Project Proponent:	
Project Location:	
Permitting Agencies:	
Checklist by:	Date:

Adequately Addressed?

YES	NO	??	N/A	
				PROJECT GOALS AND PROJECT SITING:
				Project goals fully described
				Performance standards address project goals
				Monitoring addresses performance standards/goals
				Target and sensitive species and habitats
				Environmental setting of area to be rehabilitated
				Does the (re)-created vegetation type occur in the vicinity of the implementation site
				Do baseline data support project goals and species selections
				Site analysis and rehabilitation potential
				Project constraints
				SITE PREPARATION AND IMPLEMENTATION:
				Map of area to be rehabilitated
				Land shaping, grading and drainage plan for rehabilitation site
				Evaluation of soil, i.e., source, stockpiling, fertility, compaction, amendments, etc.
				Alteration of hydrologic features
				Potential for and existing problems with invasive exotics, control measures
				List of species to be installed, ecological role and relationship to goals
				Type of plant materials (seeds, cuttings, container size)
				Source of plant materials (including genetic integrity) and feasibility of procurement
				Application rates of propagules (seeding rates, density of plantings)
				Planting zones identified by habitat type and based on site configuration and hydrology
				Planting/seeding schedule
				Irrigation: duration, frequency, water quality
				Interim erosion control measures
				Site protection measures (fencing, signing)

Adequately Addressed?

YES	NO	??	N/A	
				Monitoring and responsibility during implementation phase
				Maintenance and responsibility during implementation phase
				Cost estimate/budget
				POST-IMPLEMENTATION
				Site-specific monitoring criteria
				Monitoring methods appropriate to goals/performance standards
				Responsibility for monitoring
				Reporting mechanism and schedule
				Thresholds and remedial measures identified and adequate
				Assurance(s)/Bonding

* Created by Gail Newton and Deborah Hillyard in 1992 for SERCAL

Gambonini Stream

Before

After